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Assalamu'alaikum Warahmatullahi Wabaraakatuh



Puji dan syukur kita panjatkan kehadirat Allah SWT, Tuhan Yang Maha Kuasa atas keberhasilan Pascasarjana Universitas Lampung menerbitkan “Katalog Jurnal Mahasiswa Pascasarjana Universitas Lampung Volume 1 Tahun 2022” ini. Melalui penerbitan ini, diharapkan dapat menjadi informasi dan membuka jalan interaksi yang lebih intens antara Pascasarjana Universitas Lampung dengan *stakeholders* di luar kampus. Katalog Jurnal Mahasiswa Pascasarjana ini dimaksudkan sebagai upaya penyebarluasan hasil penelitian mahasiswa Magister (S2) sehingga pemanfaatan hasil-hasil penelitian tersebut dapat dioptimalkan dalam meningkatkan kontribusi Universitas Lampung terhadap pembangunan daerah, bangsa, negara, serta bagi kemanusiaan, dan peradaban.

Saat ini, Pascasarjana sedang bertransformasi baik pada aspek kelembagaan, penjaminan mutu maupun aspek tridarma perguruan tinggi sebagai *core business* utamanya. Pada aspek kelembagaan, Pascasarjana sedang berupaya untuk meningkatkan status menjadi sekolah yang secara teknis berimplikasi terhadap skenario pembukaan program studi baru baik pada jenjang magister maupun jenjang doktor. Pada aspek penjaminan mutu, Pascasarjana sedang mendesain sistem penjaminan mutu internal yang lebih relevan dan aplikatif sehingga target peningkatan jumlah program studi magister dan doktor yang terakreditasi unggul dapat dicapai. Adapun pada aspek tri darma, sistem pembelajaran yang relevan dengan dunia kerja terus dikembangkan termasuk di dalamnya penelitian, pengabdian, dan publikasi ilmiah dosen maupun mahasiswa.

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Wassalamu'alaikum warahmatullahi wabarakatuh

Bandar Lampung, 30 Juni 2021
Direktur.

Prof. Dr. Ahmad Saudi Samosir, ST, MT
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Abstract

In this research, the design and realization of a control system for the height and speed of the motor has been designed and implemented. The system is made to adjust the mixer automatically based on Arduino. The working principle of this system was followed, firstly, the system is given an input of height in cm unit and the rotational speed in the form of rpm unit using a 4 × 4 keypad. Arduino is used to adjust the ultrasonic sensor as an altitude reader and an optocoupler as a mixer rotary speed reader. The results of the calibration of the two sensors obtained data with a correlation coefficient are 0.991 and 0.970. The stability of the height system and the stirrer rotational speed have good precision indicated by the coefficient of variations of are 0.941% and 0.155%. The smaller the coefficient of variation, means the better the stability level of the tool. The system accuracy values for measuring the height and speed of the stirrer were 94.78% and 96.34%. So that the reading error of the two sensors is 5.22% and 3.66%. Thus the height control system and the stirrer rotational speed have a fairly good quality.

Keywords: height, rotary speed, PWM, Arduino, Ultrasonic sensor, optocoupler sensor

Abstrak

Pada penelitian ini, telah dilakukan perancangan dan realisasi sistem kontrol ketinggian dan kecepatan putar motor. Sistem dibuat untuk mengatur pengaduk secara otomatis berbasis Arduino. Prinsip kerja sistem ini yaitu mula-mula sistem diberi masukan ketinggian dalam satuan cm dan kecepatan putar berupa nilai rpm dengan menggunakan keypad 4 × 4. Arduino digunakan untuk mengatur sensor ultrasonik sebagai pembaca ketinggian dan optocoupler sebagai pembaca kecepatan putar

pengaduk. Hasil kalibrasi kedua sensor diperoleh data dengan koefisien korelasi keduanya berturut-turut 0,991 dan 0,970. Karakterisasi sensor menunjukkan bahwa sensor mempunyai linieritas yang sangat baik sehingga dapat digunakan pada alat yang dirancang. Pengujian stabilitas sistem ketinggian dan kecepatan putar pengaduk mempunyai presisi yang baik ditunjukkan dengan nilai koefisien variasi keduanya yaitu 0,941 % dan 0,155%. Semakin kecil nilai koefisien variasi maka tingkat stabilitas alat semakin baik. Nilai akurasi sistem pada pengukuran ketinggian dan kecepatan pengaduk diperoleh 94,78% dan 96,34%. Sehingga kesalahan pembacaan kedua sensor keduanya adalah 5,22% dan 3,66%. Dengan demikian sistem pengatur ketinggian dan kecepatan putar pengaduk mempunyai kualitas yang cukup baik.

Kata kunci: Ketinggian, kecepatan putar, PWM, Arduino, sensor ultrasonik, sensor *optocoupler*

PENDAHULUAN

Proses pengadukan merupakan salah satu kegiatan penting dalam proses penelitian. Proses pengadukan larutan memerlukan pengaduk yang mampu mencampurkan bahan/larutan secara *homogen*. Penggunaan alat pengaduk adalah salah satu bagian penting dalam proses pencampuran. Pengaduk yang baik yakni pengadukan dengan cara otomatis yaitu sistem pengaduk yang dapat diatur kecepatan putar ataupun variabel-variabel lain dalam penelitian.

Hingga saat ini masih ditemukan proses pengadukan secara manual maupun semi otomatis, sehingga diperlukan alat yang dapat diatur kecepatan putar secara otomatis berdasarkan kebutuhan dari penelitian yang akan dilakukan. Dalam perancangan pengaduk otomatis dibutuhkan motor penggerak yakni motor DC dan motor *stepper*.

Telah diketahui bahwa motor listrik merupakan perangkat elektromagnetis yang mengubah energi listrik menjadi energi mekanik [1]. Motor DC digunakan dalam berbagai aplikasi seperti robotika, kendaraan listrik, pabrik penggilingan baja dan lain-lain [2]. Dalam motor DC terdapat dua kumparan yaitu kumparan medan yang berfungsi untuk menghasilkan medan magnet dan kumparan jangkar yang berfungsi sebagai tempat terbentuknya gaya gerak listrik [3]. Motor DC diaplikasikan sebagai penggerak pada batang pengaduk. Sementara itu untuk memposisikan pengaduk sesuai dengan kebutuhan penelitian menggunakan motor *stepper*. Motor *stepper* merupakan perangkat elektromekanis yang mengubah pulsa elektrik menjadi gerakan mekanis diskrit. Urutan pulsa yang diterapkan secara langsung berkaitan dengan arah rotasi poros motor [4].

Komponen yang digunakan untuk mendeteksi kecepatan putar motor yakni sensor *optocoupler*, sementara itu untuk mendeteksi ketinggian ialah sensor ultrasonik. *Optocoupler* adalah komponen elektronik yang menghubungkan dua sirkuit listrik terpisah dengan menggunakan optik yang peka cahaya [5,6]. Sensor ultrasonik akan menghasilkan gelombang suara frekuensi tinggi dan mengevaluasi gema yang dipantulkan kembali ke sensor [7,8]. Besarnya jarak yang terbaca oleh sensor ultrasonik ditentukan melalui persamaan (1).

$$s = \frac{v_u t}{2} \quad (1) \quad (2.8)$$

Di mana v_u adalah besarnya kecepatan udara dan t adalah waktu yang dibutuhkan untuk mencapai ke pemancar/penerima. Pada **Persamaan (1)** kecepatan dan waktu dibagi dengan 2 karena waktu adalah waktu total yang diperlukan untuk mencapai rintangan dan kembali lagi. Jadi waktu untuk mencapai halangan hanya setengah dari total waktu yang diambil [9].

Kedua sensor tersebut dikontrol oleh Arduino Mega, dengan demikian Arduino Mega sebagai mikrokontroler dalam penelitian. Mega merupakan papan mikrokontroler berdasarkan ATmega2560. Alasan menggunakan Arduino jenis ini karena memiliki lebih banyak digital dan analog pin dibandingkan dengan Arduino jenis lain serta pemrograman yang mudah [10,11]. Salah satu fungsi lain dari Arduino Mega pada penelitian ini yaitu memiliki fungsi *Pulse Width Modulation (PWM) built-in* sehingga memudahkan untuk merancang rangkaian tambahan lain dalam penelitian ini [2].

PWM secara luas digunakan dalam aplikasi elektronika untuk mengontrol konverter daya (DC / DC, DC / AC dan lain sebagainya) [12]. PWM difungsikan untuk mengontrol kecepatan motor DC. Tegangan Tegangan keluaran DC diatur ke nilai yang diinginkan dengan menyesuaikan nilai tegangan referensi, sehingga memodifikasi *duty cycle*/siklus kerja sinyal PWM didapat **Persamaan (2)**.

$$V_o = DV_{in} = \frac{t_{on}}{T_s} V_{in} = \frac{V_{ref}}{V_{tr}} V_{in} \quad (2) \quad (2.6)$$

Dengan V_{in} adalah konverter tegangan *input* DC, D adalah siklus kerja sinyal PWM ($0 \leq D \leq 1$), t_{on} adalah sinyal PWM waktu *on*, T_s adalah periode pengalihan konverter dan V_{tr} adalah amplitudo gelombang segitiga. Adapun formula yang digunakan untuk menghitung besarnya siklus kerja terdapat pada **Persamaan (3)**.

$$\text{Siklus Kerja} = \frac{t_{ON}}{t_{ON} + t_{OFF}} \times 100 \quad (3)$$

Dengan t_{ON} adalah siklus *high* pada sebuah sinyal dan t_{OFF} siklus *low* pada sebuah sinyal.

Pada penelitian ini dirancang kecepatan putar pengaduk dengan rentang 900 hingga 3500 rpm, sementara itu ketinggian pengaduk dirancang dari ketinggian 14 hingga 60 cm. Tujuan dilakukannya penelitian ini untuk membuat pengaduk larutan yang mampu secara otomatis mengatur kecepatan putar batang pengaduk dalam rpm dan ketinggian batang pengaduk dalam cm. Dengan demikian kedua variabel tersebut diintegrasikan dalam satu sistem.

Manfaat dari penelitian ini yaitu dengan adanya pengaturan kecepatan pengaduk dan pengaturan posisi ketinggian pengaduk, pengadukan diharapkan dapat membantu mempermudah peneliti dan laboran dalam melakukan pencampuran larutan secara otomatis dengan melakukan penyesuaian kecepatan putar pengaduk dan ketinggian pengaduk yang menyesuaikan dengan kapasitas karutan yang digunakan. Sehingga larutan dapat tercampur secara *homogen* (tercampur secara menyeluruh).

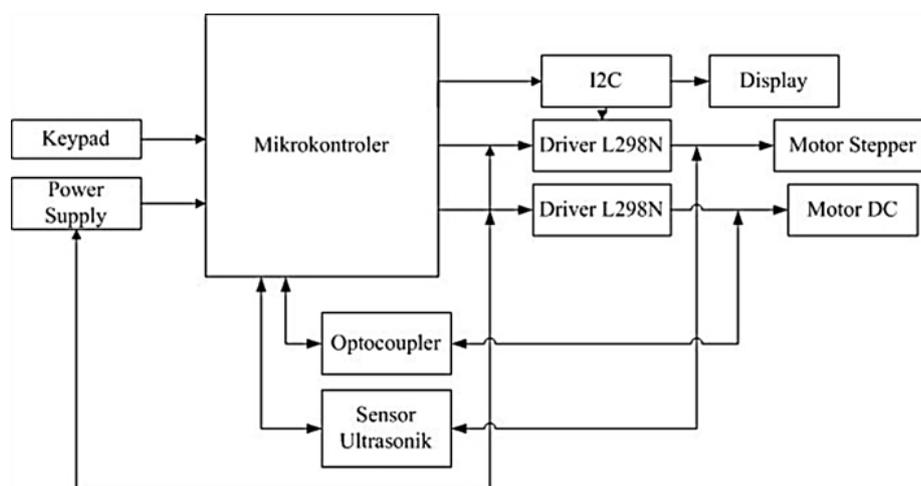
METODE PENELITIAN

Perancangan sistem pada penelitian ini terdiri dari dua bagian utama, yaitu perancangan pada perangkat keras dan perangkat lunak. Perancangan perangkat keras meliputi catu daya, keypad 4×4, motor DC, motor stepper, driver L298N, I2C, sensor ultrasonik, dan sensor optocoupler.

Sementara itu perancangan perangkat lunak terdiri dari perancangan program untuk program tombol pada Keypad, program pengaturan putar motor baik motor DC maupun motor stepper, program untuk tampilan pada LCD, program perhitungan jumlah rpm dan program ketinggian. Adapun bahasa yang digunakan pemrograman pada penelitian ini adalah bahasa C.

Berdasarkan blok diagram pada **Gambar 1** dapat didefinisikan catu daya (*power supply*) bertindak sebagai penyuplai tegangan pada sistem yang dirancang terdapat 2 jenis catu daya yang digunakan yaitu catu daya 5 Volt dan catu daya dengan tegangan 12 Volt, kemudian keypad 4 × 4 sebagai komponen yang berfungsi untuk memasukkan nilai ketinggian dan kecepatan putar pengaduk sesuai dengan kebutuhan penelitian.

Perancangan sistem kontrol kecepatan dan ketinggian motor ditunjukkan pada diagram blok **Gambar 1**.



Gambar 1. Diagram blok perangkat keras pengatur kecepatan dan ketinggian pengaduk.

Berdasarkan **Gambar 1** terlihat bahwa hasil masukan dari keypad 4×4 memberikan perintah kepada Arduino untuk mengaktifkan driver L298N yang nantinya akan mengatur arah pergerakan dari motor stepper dan motor DC. Ketinggian pengaduk akan

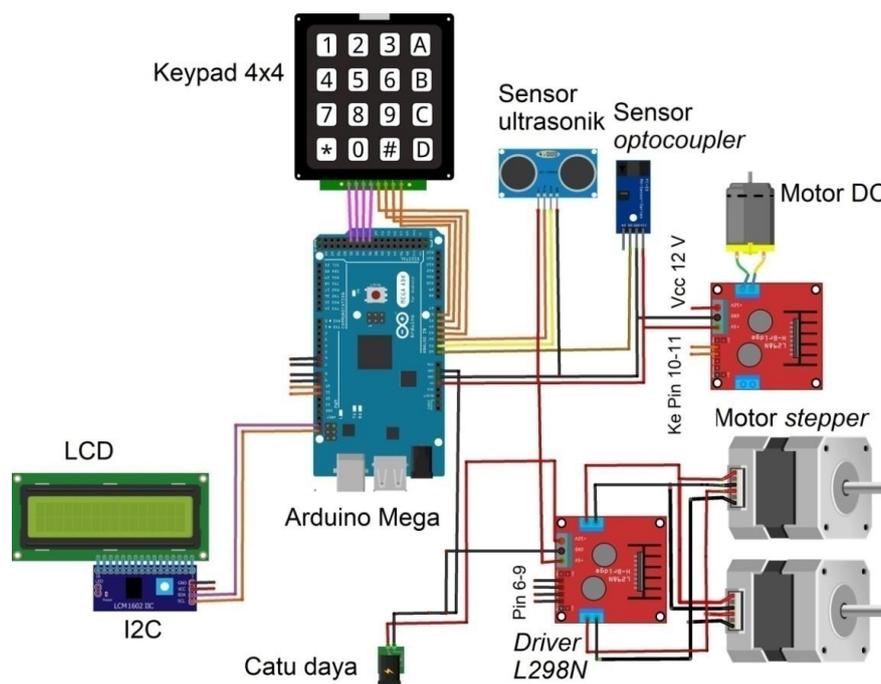
dikontrol oleh sensor ultrasonik dan kecepatan putar pengaduk akan terbaca oleh sensor *optocoupler*

Arduino berfungsi sebagai pembangkit pulsa PWM berdasarkan nilai masukan dari *keypad* 4×4. PWM akan diteruskan ke driver untuk mengontrol arah putaran dan percepatan motor. Nilai PWM akan dikonversi ke dalam rpm (*revolutions/minutes*), sehingga masukan kecepatan putar dari *keypad* 4×4 sudah dalam satuan rpm. Hasil pembacaan kecepatan putar aktual dari motor yang menggerakkan batang pengaduk oleh sensor *optocoupler* akan dibandingkan dengan *tachometer*.

Hasil perbandingan dengan alat ukur pembanding digunakan untuk mendapatkan nilai kecepatan putar pengaduk sebenarnya. Sementara itu pada pengaturan ketinggian pengaduk, masukan dari *keypad* 4×4 berupa masukkan ketinggian dalam cm akan memberikan perintah ke sensor ultrasonik yang nantinya akan memberikan umpan balik kepada mikrokontroler untuk menggerakkan motor *stepper* yang diarahkan oleh driver L298N arah dan perputarannya.

Hasil dari pembacaan sensor ultrasonik akan dibandingkan dengan mistar dengan skala 0-100 cm. sementara hasil pembacaan sensor *optocoupler* akan dibandingkan dengan *tachometer* digital.

Skema rangkaian sistem pengaduk dapat dilihat pada **Gambar 2**.



Gambar 2. **Skema rangkaian sistem pengaduk.** Pada Gambar 2 tampak rangkaian komponen secara keseluruhan yang dirangkai berdasarkan kebutuhan dari masing-masing komponen.

Hasil dari pengukuran akan dianalisis menggunakan akurasi sistem, tingkat kesalahan hingga tingkat kestabilan sistem. Persamaan yang digunakan untuk menghitung persentase kesalahan (*error*), akurasi, presisi dan lineritas

HASIL DAN PEMBAHASAN

Sumber tegangan merupakan komponen penting untuk menjalankan program pada penelitian. Pada penelitian ini sumber tegangan yang digunakan terdiri dari 2 (dua) macam yaitu sumber tegangan 5 Volt dan 12 Volt. Adapun sumber tegangan 5 Volt ditujukan untuk menyuplai tegangan ke Arduino Mega sementara sumber tegangan 12 volt untuk menggerakkan motor *stepper* dan motor DC.

Keluaran tegangan 5 V dari Arduino menyuplai sensor ultrasonik dan sensor *optocoupler*. Sensor ultrasonik pada penelitian ini berfungsi sebagai pengatur ketinggian pengaduk. Secara sederhana ketika gelombang ultrasonik memancarkan gelombang maka logika pin Echo = 1 (HIGH). Selama gelombang ultrasonik masih merambat (belum memantul kembali) logika pin Echo = 1. Namun setelah gelombang ultrasonik memantul dan kembali terdeteksi oleh sensor penerima, maka pin Echo = 0 (LOW). Setelah sensor ultrasonik membaca sinyal pada ketinggian tertentu maka motor *stepper* akan menggerakkan ketinggian pengaduk sesuai dengan data masukkan yang diinginkan.

Sementara itu, sensor *optocoupler* akan membaca perputaran motor DC melalui piringan bercelah yang diletakkan di bawah motor DC tepat di celah sensor *optocoupler*.

Piringan bercelah difungsikan sebagai alat bantu guna membaca kecepatan putar motor DC dalam satuan rpm. Pada penelitian ini digunakan piringan dengan 18 lubang. Piringan bercelah yang digunakan pada dua keadaan yaitu gelap dan terang. Keadaan inilah yang dapat mengaktifkan dan menonaktifkan *optocoupler*. Banyaknya keadaan gelap atau keadaan terang dalam waktu tertentu dapat dihitung sebagai kecepatan putar motor.

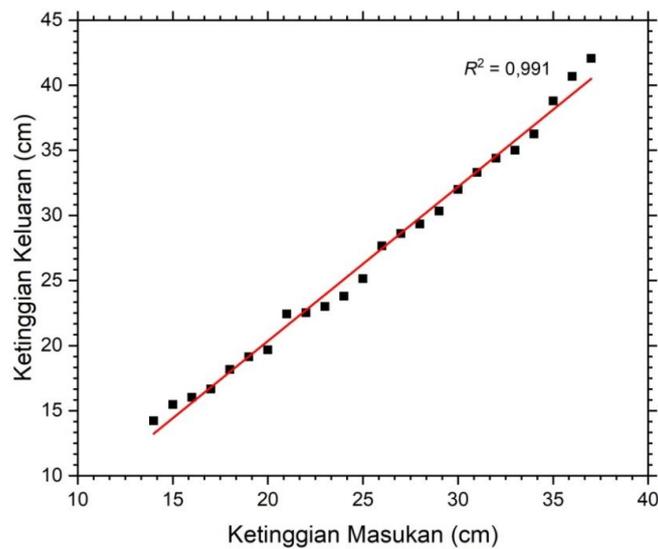
1) Kalibrasi Sensor yang digunakan

Proses kalibrasi dilakukan untuk melihat akurasi dari sensor ultrasonik dan *optocoupler* dengan cara membandingkannya dengan alat ukur standar. Hasil pembacaan sensor ultrasonik akan dibandingkan dengan penggaris dengan skala 0-100 cm, sedangkan sensor *optocoupler* dibandingkan dengan tachometer.

Saat dilakukan kalibrasi pada sensor ultrasonik terjadi pembacaan yang konstan yaitu menunjukkan angka -1 atau +1 dari masukkan yang dilakukan, hal tersebut terjadi dikarenakan pada saat sensor ultrasonik memberhentikan program secara otomatis untuk mengaktifkan reset, sehingga nilai akhir tidak terbaca dikarenakan sensor ultrasonik langsung mereset pembacaan ketinggiannya.

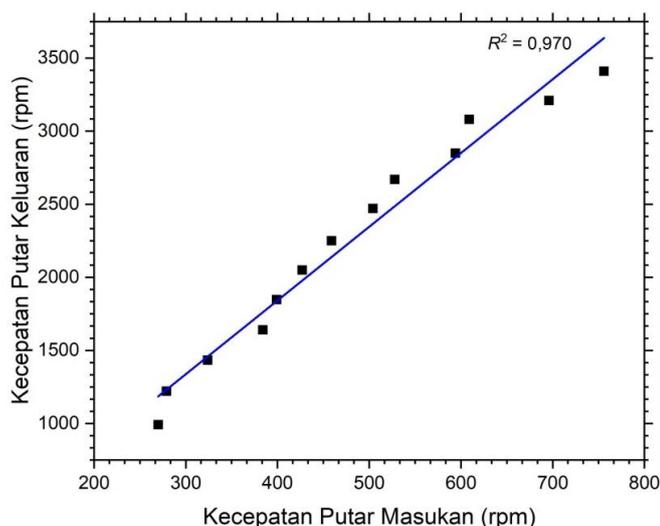
Berdasarkan analisis yang telah dilakukan dari hasil pengujian didapatkan nilai R^2 sebesar 0,991 dan didapatkan besar persamaan ketinggian hasil pengukuran yang ditunjukkan dengan nilai koefisien ketinggian masukan (X) sebesar 1,184942 dan nilai konstanta sebesar -3,3535. Dari proses kalibrasi didapatkan skala pembacaan sensor ultrasonik yaitu dari 14 cm hingga 60 cm.

Hasil dari uji kalibrasi sensor ultrasonik dapat dilihat pada **Gambar 3**.



Gambar 3. Grafik hasil dari uji kalibrasi sensor ultrasonik

Uji kalibrasi sensor *optocoupler* pada pengukuran kecepatan putar motor dimulai pada kecepatan putar 900 rpm hingga 3500 rpm. Saat motor DC berputar kecepatan putar langsung terdeteksi oleh sensor *optocoupler*, nilai kecepatan putar tersebut muncul pada tampilan LCD. Kemudian, saat itu juga dilakukan pengukuran secara langsung dengan menggunakan tachometer dan didapatkan nilai perbandingan antara kecepatan putar masukan dengan kecepatan putar keluaran. Dari pengujian tersebut didapatkan nilai R^2 sebesar 0,970 dan didapatkan persamaan kecepatan putar motor hasil pengukuran yang ditunjukkan dengan nilai koefisien kecepatan motor masukan sebesar 5,044 dan konstanta sebesar -176,7 dan didapatkan batas pengukuran pembacaan sensor *optocoupler* dari 900 rpm hingga 3500 rpm. Hasil dari uji kalibrasi sensor ultrasonik dapat dilihat pada **Gambar 4**.



Gambar 4. Grafik hasil dari uji kalibrasi sensor *optocoupler*. **Persentase Kesalahan Alat yang Dirancang**

Hasil analisis didapatkan persentase kesalahan alat pada parameter ketinggian sebesar 1,555%. Sementara itu persentase alat pada parameter kecepatan putar pengaduk yaitu 0,639%. Dari angka tersebut terlihat bahwa alat yang dirancang pada pengatur ketinggian relatif baik dikarenakan nilai kesalahan yang masih di bawah 10%. Terdapatnya kesalahan dapat disebabkan oleh beberapa faktor.

Adapun faktor yang menjadi penyebab terjadinya kesalahan pada sensor ultrasonik dan *optocoupler* meliputi kedudukan sensor ultrasonik dan *optocoupler* yang masih belum stabil. Pada sensor ultrasonik dalam membaca ketinggian dibantu dengan pergerakan motor *stepper*, sensor ultrasonik bergerak ke atas dan ke bawah dampak dari pergerakan motor *stepper* yang saling berlawanan, dan pada saat pengoperasian terdapat kendala pada saat motor *stepper* bekerja melewati lintasan statif besi yang tingkat kekasarannya berbeda. Sementara itu kesalahan pada sensor *optocoupler* disebabkan pembacaan piringan yang bergerak menyesuaikan dengan pergerakan motor DC yang begitu cepat. Faktor lain yang menyebabkan hal tersebut yaitu kedudukan pengaduk tidak tetap (terus bergerak) menyesuaikan dengan kebutuhan saat proses pengadukan, hal ini pun mempengaruhi kestabilan pada kedudukan sensor ultrasonik dan sensor *optocoupler*.

2) Akurasi Alat yang Dirancang

Uji akurasi digunakan untuk mengetahui kakuratan sistem yang dirancang. Pada pengambilan data parameter ketinggian dilakukan pengambilan data dimulai dari ketinggian pengaduk 14 cm hingga 60 cm dengan melakukan pengulangan sebanyak 3 kali. Sedangkan pada kecepatan putar pengaduk dilakukan pengambilan data pada masukan PWM dari 50 hingga 170 menghasilkan kecepatan putar motor 900 rpm hingga 3460 rpm. Setelah dianalisis didapatkan rata-rata nilai akurasi untuk parameter ketinggian pengaduk sebesar 98,455% dan rata-rata akurasi untuk kecepatan putar pengaduk sebesar 99,361%. Akurasi sistem kerja alat yang dirancang meliputi pengaturan ketinggian dan kecepatan putar motor mempunyai nilai mendekati 100%, hal itu menunjukkan bahwa alat dapat bekerja dengan baik. Alat mempunyai tingkat akurasi yang sangat baik karena sebelumnya telah dilakukan pengujian kalibrasi dari sensor ultrasonik sebagai pengatur ketinggian dan sensor *optocoupler* sebagai pengatur kecepatan putar motor.

3) Presisi Alat yang Dirancang

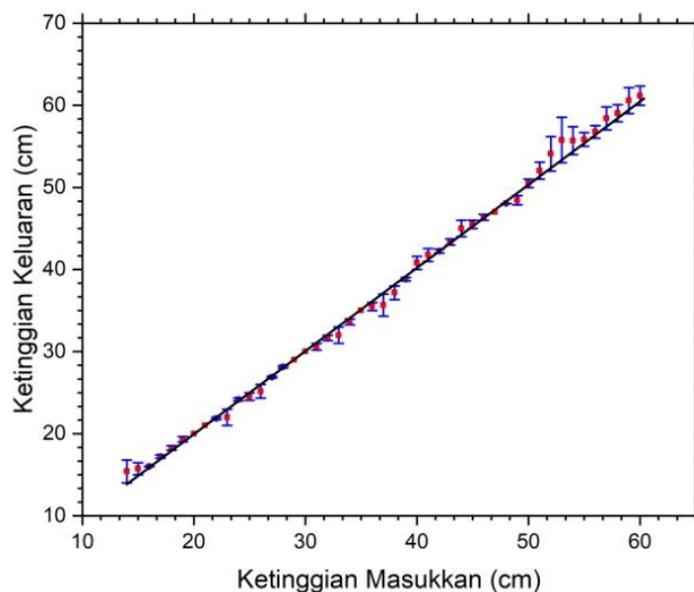
Teknik pengujian presisi pada masing-masing parameter dilakukan pengujian sebanyak 3 (tiga) kali, dari hasil pengujian akan ditarik nilai rata-rata kemudian hasil rata-rata akan disandingkan dengan data masukkan yang kemudian dianalisis untuk mengetahui nilai standar deviasi (**SD**) dan koefisien variasi (**KV**). Persamaan yang digunakan untuk menghitung besarnya presisi sistem pengaduk dapat menggunakan **Persamaan (4)**.

$$SD = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}}$$

$$KV = \frac{SD}{\bar{X}} \times 100\% \quad (4)$$

Dengan X_i adalah hasil penelitian setiap percobaan, \bar{X}_n adalah *output* rata-rata dari parameter penelitian, SD adalah standar deviasi, n adalah jumlah sampel dan KV adalah koefisien variasi. Uji presisi bertujuan untuk menentukan tingkat kestabilan alat yang dirancang.

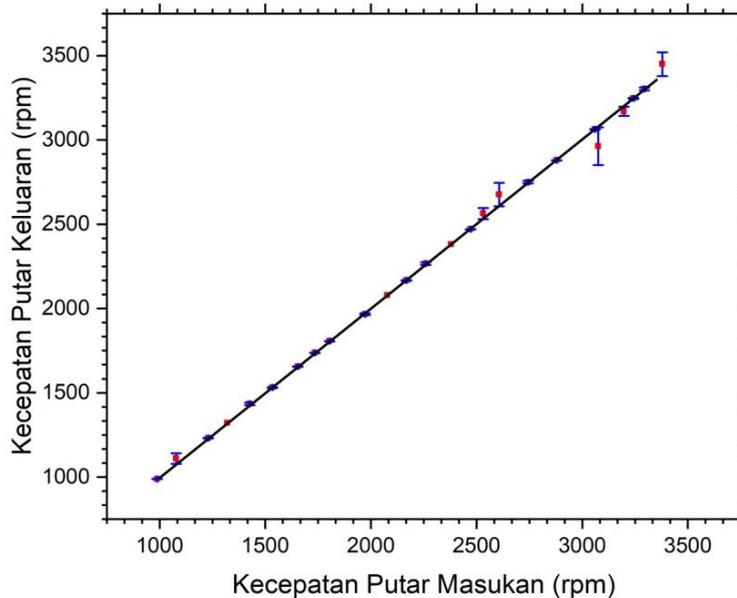
Visualisasi grafik presisi ketinggian terdapat pada **Gambar 3**.



Gambar 3. Grafik presisi sistem pada parameter ketinggian pengaduk hasil pembacaan sensor ultrasonik.

Berdasarkan **Gambar 3** terlihat bahwa dari ke tiga garis pada grafik presisi sistem pada parameter ketinggian pengaduk saling bersinggungan, hal tersebut menunjukkan bahwa sistem pengaduk yang dirancang mempunyai kestabilan yang sangat baik. Setelah dianalisis sensor ultrasonik yang membaca ketinggian pengaduk mempunyai presisi yang baik yang dibuktikan dengan nilai koefisien variasi masing-masing sebesar 0,941%.

Adapun visualisasi grafik presisi dari sensor *optocoupler* pada pembacaan kecepatan putar pengaduk ditunjukkan pada **Gambar 4**.



Gambar 4. Grafik presisi sistem pada parameter kecepatan putar pengaduk

Berdasarkan **Gambar 4** tampak bahwa sensor *optocoupler* mempunyai nilai presisi atau kestabilan yang baik yang ditunjukkan garis-garis yang mewakili pengulangan percobaan yang hampir berhimpitan terhadap garis masukan. Selain pada **Gambar 4**, kestabilan sistem pengaduk pada parameter kecepatan pengaduk ditunjukkan pada hasil analisis didapatkan nilai koefisien variasi sebesar 0,155%. Berdasarkan hasil tersebut nilai koefisien variasi sangat kecil bahkan di bawah 1%, hal ini menunjukkan alat yang dirancang sangat presisi dikarenakan semakin kecil nilai koefisien variasi maka tingkat stabilitas alat semakin baik [13].

KESIMPULAN

Telah direalisasikan sistem kontrol kecepatan dan ketinggian pengaduk menggunakan sensor *optocoupler* dan ultrasonik berbasis Arduino. Sensor ultrasonik dan sensor *optocoupler* berkualitas baik dibuktikan dengan hasil uji kalibrasi ketinggian dan kecepatan pengaduk dengan nilai R^2 masing-masing 0,939 dan 0,995. Keluaran ketinggian pengaduk memiliki linearitas dan akurasi yang sangat baik dengan R^2 sebesar 0,9970 dan persentase akurasi sebesar 98,455%. Begitupun dengan keluaran kecepatan pengaduk untuk linearitasnya mempunyai nilai yang sangat baik ditunjukkan dengan R^2 sebesar 0,979 dan tingkat akurasinya 98,445%. Terdapat tingkat kesalahan pengukuran pada sistem yang dirancang dengan nilai 1,555% dan 0,639%. Keluaran ketinggian dan kecepatan putar pengaduk memiliki tingkat presisi yang sangat baik dinyatakan dengan koefisien variasi masing-masing sebesar 0,941 % dan 0,155%. Semakin kecil nilai Koefisien Variasi maka tingkat presisi alat semakin baik.

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APPLICATION OF VECTOR AUTOREGRESSIVE WITH EXOGENOUS VARIABLE: CASE STUDY OF CLOSING STOCK PRICE OF PT INDF.TBK AND PT ICBP.Tbk

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Abstract

Multivariate time series are widely used in various fields such as finance, economics, and the stock market. One analysis model that is widely used for multivariate time series data is the VAR model. Vector autoregressive (VAR) is a model used to describe the relationship between several variables. The VAR model provides an alternative approach that is very suitable for forecasting purposes and is very suitable for solving economic data problems. The variables used in this study consisted of endogenous variables with closing prices of ICBP and INDF shares and exogenous variables with exchange rates collected from January 2017 to July 2020. In this study, the best model, VARX (1,0), was obtained. also the relationship between variables through the impulse response function and granger causality. Furthermore, forecasting is also carried out for the next 30 days using the best model, VARX (1,0).

Keyword: vector autoregressive with exogenous variable, granger causality, impulse response function, forecasting..

Introduction

Covid-19 (Corona Virus Disease 2019) is a disease caused by SARSCov-2 (Severe Acute Respiratory Syndrome Coronavirus 2) or better known as Corona Virus. The Covid-19 case was first discovered in Wuhan Province, China in December 2019. This virus is not only in its home country, but the virus has spread throughout the world, including Indonesia. Of course this outbreak has had a negative impact on several sectors, one of which is the Indonesian economy and also has a significant impact on the stock market value of various sectors. In this study, the value of shares from the consumer sector is used because this sector is one of the sectors whose products are

still used by the people in the midst of this pandemic and exchange rates are also used, namely the price of a currency from a country that is measured or expressed in currency. other money. Exchange rates play an important role in spending decisions, because they allow us to translate prices from various countries into the same language. Financial data or economic data collected in the same time interval is often referred to as time series

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data. Multivariate time series are very popular in various fields such as finance, economics, stock market, and earth science, for example, meteorology [1]. In a multivariate time series analysis, not only the nature of the individual series but also the possible cross relations between time series data are discussed. The application of an autoregressive vector model (VAR) has been widely discussed by [24]. The VAR model can be used for structural analysis. In structural analysis, certain assumptions are imposed on the causal structure of the data being examined, and the causal impact resulting from unexpected shock or innovation for certain variables is studied. This causal impact is usually summarized in Granger causality and impulse response function (IRF) [5-7]. VAR provides an alternative approach that is very suitable for forecasting purposes. This model can be called an approach to the reduced form of a simultaneous structured system of equations. The VAR model is based on the historical data provisions of the variables to be predicted [8]. In this study involving exogenous variables, this model is extended to VAR with exogenous variables or VARX [[6],[9]].

Statistical Model

Multivariate time series data are considered as multiple time series data simultaneously. This is a branch of multivariate statistical methods, but is related to dependent data [4]. The main objectives of multivariate time series analysis to study the dynamic relationship between or between variables and to improve the accuracy of predictions [9-12]. In multivariate time series, k-dimensional time series data or vector time series data are used [13]. One of the multivariate time series data analysis is the Vector Autoregressive (VAR) model. The VAR model, for example X_t with $t = 0, 1, \dots$, becomes the pcomponent, full rank, zero average, covariance stationarity process. It is shown that the stationary process with full rank has a representation of the one-sided moving average or a unique Moving Average of the form [14]

$$X_t = \epsilon_t + \Gamma_1 \epsilon_{t-1} + \Gamma_2 \epsilon_{t-2} + \dots \quad (1)$$

Where ϵ_t is component p zero which means that that the process orthogonal. Under general condition, (1) can be written as

$$(1 - \psi_1 L - \psi_2 L^2 - \dots) X_t = \epsilon_t \quad (2)$$

Or equivalent to

$$X_t = (\psi_1 L - \psi_2 L^2 - \dots) + \epsilon_t \quad (3)$$

$$= \begin{bmatrix} \psi_{11}(L) & \dots & \psi_{1p}(L) \\ \vdots & \ddots & \vdots \\ \psi_{p1}(L) & \dots & \psi_{pp}(L) \end{bmatrix} X_t + \epsilon_t \tag{4}$$

[15] where L is lag operator $LX_t = X_{t-1}$ and

$$\psi_{ij}(L) = \sum_{k=1}^{\infty} \psi_{ijk} L^k \tag{5}$$

VAR (p) and VARX (p,q) Models

Vector autoregressive (VAR) is a model used to describe the relationship between several variables. This model is a generalization form of the univariate AR model. All variables in VAR are arranged symmetrically by including equations that explain the development of each variable based on its own lag and the lag of all other variables in the model. The general model for VAR (p) is as follows [11],

$$\begin{aligned} \dot{y}_t &= \Phi_1 \dot{y}_{t-1} + \dots + \Phi_p \dot{y}_{t-p} + a_t \\ &= \sum_{i=1}^p \Phi_i \dot{y}_{t-i} + a_t \end{aligned} \tag{6}$$

where,

- \dot{y}_t = $m \times 1$ vector variable at time t , with $\dot{y}_t = y_t - \mu$
- Φ_i = $m \times m$ matrix of order p ,
- a_t = $m \times 1$ vector residuals at time t .

VARX is Vector Autoregressive model with exogenous variable involve in the model. VARX Model (p,q) is defined as follows:

$$\dot{y}_t = \sum_{i=1}^p \Phi_i \dot{y}_{t-i} + \sum_{i=1}^q \Theta_i x_{t-i} + a_t \tag{7}$$

where,
 $\Phi(B) = I_k - \Phi_1 B - \dots - \Phi_p B^p$
 $\Theta_i(B) = I_k - \Theta_{i1} B - \dots - \Theta_{iq} B^q$

$\dot{y}_t = ((y_{1t} - \mu), \dots, (y_{kt} - \mu))$
 $a_t = (a_{1t}, \dots, a_{kt})'$ $x_t = (x_{1t}, \dots, x_{rt})'$

Φ_i is $k \times k$ matrix and Θ_i^* is $k \times r$ matrix parameters.

Condition for Stationary

The stationarity of multivariate time series data can be tested by looking at the data graph whether the data fluctuates around a certain number or not; if not, then the data is not stationary. Statistically, we can check stationary data using the augmented

dickey fuller test (ADF Test) or unit root test. In addition, it can also check the autocorrelation function (ACF) graph; if ACF decay very slowly, it can be said that the data is not stationary. In Unit-Root Test with lag-p, the model with constants is defined as follows:

$$\Delta X_t = \alpha + \phi X_{t-1} + \sum_{i=1}^p \phi_i^* \Delta X_{t-i} + u_t \quad (8)$$

Where $\Delta X_t = X_t - X_{t-1}$ and u_t is white noise. The null hypotheses is $H_0 : \phi = 0$ against the alternative hypotheses $H_a : \phi < 0$. The test statistics is τ (tau) with the distribution approximately t-distribution [9]. For significant level ($\alpha = 0.05$), H_0 is rejected if $\tau < -2.57$ or if $P - value < 0.05$ [10][16]. The test statistics is as follows:

$$ADF \tau = \frac{\phi}{se(\phi)} \quad (9)$$

Test for Granger Causality

Granger causality is used to look at the inter-dependency structure of the system that underlies multivariate time series [17-19]. The concept of Granger causality was introduced by Granger [11], the Granger variable causes other variables to increase if the coefficients are positive in the model (10). In a multivariate time series, the other observed variables are included in two autoregressive vector models (VAR) for Y. The econometric test of the observed data, for example, Y Granger Cause X, can be based on the following model [6]:

$$X_t = c_1 + \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \dots + \alpha_p X_{t-p} + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \dots + \beta_p Y_{t-p} + u_t \quad (10)$$

Impulse Response Function

VAR Model can be written as vector MA (∞) as follows:

$$X_t = \mu + u_t + \Psi_1 u_{t-1} + \Psi_2 u_{t-2} + \dots$$

So that, matrix Ψ_s has an interpretation as follows:

$$\frac{\partial X_{t+s}}{\partial u_t} = \Psi_s$$

Row i, column j of the element Ψ_s indicates the consequences of the increase one unit in innovation variable j at time t (u_{jt}) for the value of variable ith at time t+s ($X_{i,t+s}$), assuming that all other innovation are constant. If the first element u_t is changed as big as δ_1 , at the same time, the second element is changed as big as δ_2, \dots , and the nth element is changed as big as δ_n , then the joint effects of those changed on the vector value (X_{t+s}) become

$$\Delta X_{t+s} = \frac{\partial X_{t+s}}{\partial u_{1t}} \delta_1 + \frac{\partial X_{t+s}}{\partial u_{2t}} \delta_2 + \dots + \frac{\partial X_{t+s}}{\partial u_{nt}} \delta_n = \Psi_s \delta \quad (11)$$

Plot of the row i, column j of the element Ψ_s

$$\frac{\partial X_{i,t+s}}{\partial u_j_t}$$

The function s is called as Impulse Response Function [4].

Forecasting

Forecasting is one of the main objectives in multivariate time series data analysis. Forecasting in the VAR (p) model is basically similar to the estimate in the univariate AR (p) model. First, the basic idea in the forecasting process is that the best VAR model must be identified using certain criteria to choose the best model. After the model is found, it can be used for estimation. Therefore, forecasting will be obtained from the best VARX (p, q) model [4].

Result and Discussion

The data used in this study are ICBP and INDF stock closing price data taken from the January 2017 to July 2020 period and exchange rate data also taken from the January 2017 to July 2020 period. ICBP and INDF [20] [21] data are taken from Yahoo Finance and the value of the exchange rate is taken from Bank Indonesia. The plot of the data can be seen in Figure 1. The text of your paper should be formatted as follows:

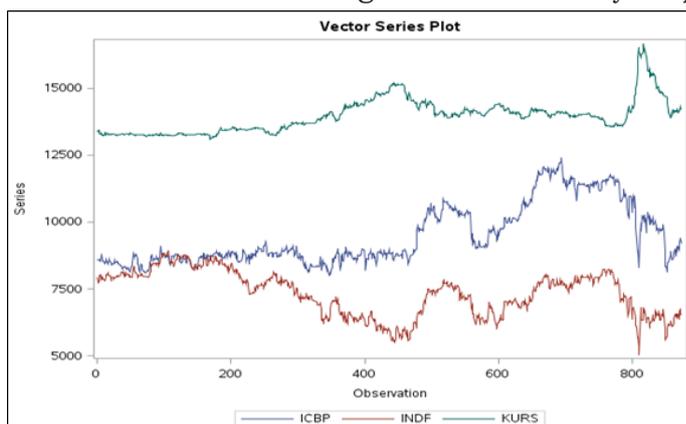


Figure 1. Plot of Exchange rate, ICBP, and INDF from January 2017 to July 2020

In Figure 1. It can be seen that ICBP, INDF, and KURS data are not stationary. The exchange rate data from the first day to the 200th day of the chart looks flat, from the 200th to 400th data the trend rises slowly and fluctuates and from the 400th day the trend declines and fluctuates until the 800th day and then on the 10th day 800 graphs show a trend to increase dramatically and decrease slowly again. ICBP data from the first day fluctuated until the 450th day and increased from 450th to the 550th day and then on the 550th day increased again until the 700th day and the data tended to decrease and fluctuate until the last day. INDF data from the first day fluctuated until the 450th day and decreased from the 450th day to the 550th day and then on the 550th day increased again until the 700th day and the data tended to decrease and fluctuate until the last day. Next, a stationary test was performed on the data using the ADF test.

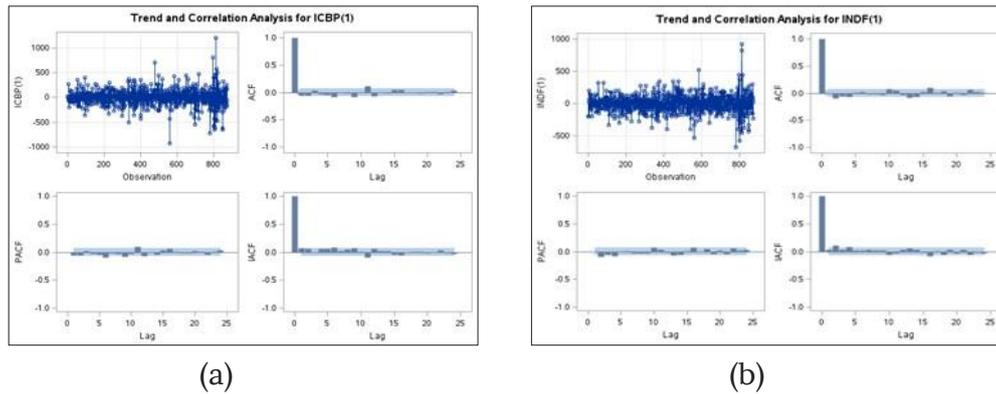


Figure 2. Residual plot, ACF, PACF, and IACF after differentiation with $d = 1$ for (a) ICBP, (b) INDF

Figure 2 (a) and Figure 2 (b) are plots of the ADF test results after differencing. It can be seen that, after differencing data fluctuates around certain numbers. This shows that after differencing the data becomes stationary. This can also be seen in Table 1. Namely the ADF test results that show the p-value of the ICBP and INDF data of $p < 0.0001$. Therefore, it can be concluded that this data is stationary on the first differencing.

Table 1. Augmented Dickey Fuller Unit Root test for data ICBP and INDF before and after differentiation ($d=1$).

Variable	Type	Before differentiation				After Differentiation			
		Rho	P value	Tau	P value	Rho	P value	Tau	P value
ICBP	Zero Mean	-0.0477	0.6720	-0.10	0.6487	-1045.53	0.0001	-22.82	<.0001
	Single Mean	-8.0345	0.2152	-2.04	0.2704	-1045.72	0.0001	-22.81	<.0001
	Trend	-14.4198	0.2042	-2.49	0.3323	-1046.37	0.0001	-22.81	<.0001
INDF	Zero Mean	-0.2937	0.6161	-0.56	0.4760	-1066.45	0.0001	-23.06	<.0001
	Single Mean	-10.8308	0.1100	-2.29	0.1763	-1066.83	0.0001	-23.05	<.0001
	Trend	-14.8710	0.1879	-2.73	0.2251	-1066.86	0.0001	-23.04	<.0001

Furthermore, to get the best model, it was selected using the AICC, HQC, AIC, and SBC information criteria from each model. The best model is the model that has the smallest value of the information criteria and the results of the analysis are presented in Table 2. Based on Table 2. The best model with SBC criteria is VARX (1,0) with a minimum value of 19,54635, with HQC criteria, namely VARX (2,0) with a minimum value of 19.50884, and the AICC and AICC criteria are VARX (4,0) with a minimum value of 19.4761 and 19.47556.

Table 2. Comparison of the criteria for VARX (1,0)–VARX (5,0) models

	Information Criteria			
	AICC	HQC	AIC	SBC
VARX (1,0)	19.50267	19.51933	19.50258	19.54635*
VARX (2,0)	19.48389	19.50884*	19.4837	19.54941
VARX (3,0)	19.4792	19.51241	19.47885	19.56655
VARX (4,0)	19.4761*	19.51755	19.47556*	19.58528
VARX (5,0)	19.47936	19.52901	19.47858	19.61036

After obtaining several candidate best models, VARX (1,0), VARX (2,0), and VARX (4,0). Judging from the schematic representation of the estimated parameters of each of these models. It can be seen in Table 3. There are 2 parameters and 3 significant parameters in AR1 for the VARX (1,0) and VARX (4,0) models and there are 5 significant parameters in AR1-2 for the VARX (2,0) model, and there are no significant parameters in AR3 and AR4. So the best model used is the VARX model (1,0).

Table 3. Schematic representation of parameter estimates for VARX (1,0), VARX (2,0), and VARX (4,0) models

Model	Variable/lag	C	XL0	AR1	AR2	AR3	AR4
VARX (1,0)	ICBP	.	.	+			
	INDF	+	-	+			
VARX (2,0)	ICBP	.	.	+	..		
	INDF	+	-	++	-.		
VARX (4,0)	ICBP	.	.	+
	INDF	.	.	++

+ is $> 2 \times \text{std error}$, - is $< -2 \times \text{std error}$, . is between, * is N/A

Table 4. Statistical test for the parameters used in model

Equation	Parameter	Estimate	Standard Error	t Value	Pr > t	Variable
ICBP	CONST1	371.53411	283.85174	1.31	0.1909	1
	XL0_1_1	-0.01272	0.01636	-0.78	0.4368	KURS(t)
	AR1_1_1	0.99221	0.00546	181.86	0.0001	ICBP(t-1)
	AR1_1_2	-0.01626	0.01192	-1.37	0.1726	INDF(t-1)
INDF	CONST2	656.11496	236.68721	2.77	0.0057	1
	XL0_2_1	-0.03171	0.01364	-2.33	0.0203	KURS(t)
	AR1_2_1	0.00180	0.00455	0.40	0.6920	ICBP(t-1)
	AR1_2_2	0.96834	0.00994	97.46	0.0001	INDF(t-1)

Based on Table 4. VARX(1,0) model can be written as follows:

$$\Gamma_t = \begin{pmatrix} 371.53411 \\ 656.11496 \end{pmatrix} + \begin{pmatrix} 0.99221 & -0.01626 \\ -0.00180 & 0.96834 \end{pmatrix} \Gamma_{t-1} + \begin{pmatrix} -0.01272 \\ -0.03171 \end{pmatrix} \Psi_t + \varepsilon_t \quad (12)$$

Where $\Psi_t = \text{ExR values}_t$. VARX(1,0) model is also can be written as two univariate model as follows:

$$\Gamma_{1t} = 371.5341 + 0.99221 \Gamma_{1t-1} - 0.01626 \Gamma_{2t-1} - 0.03171 \Psi_t + \varepsilon_{1t} \quad (13)$$

and

$$\Gamma_{2t} = 656.11496 - 0.00180 \Gamma_{1t-1} + 0.96834 \Gamma_{2t-1} - 0.01272 \Psi_t + \varepsilon_{2t} \quad (14)$$

The results of the statistical test of the parameters VARX(1,0) model is given in Table 4, and for model (13) and (14) are given in Table 5. The results of the test for model Γ_{1t} (ICBP) is very significant with p-value < 0.0001 and R-square 0.9802 this means that 98.02% variation of ICBP can be accounted for variables lag Γ_{1t-1} , Γ_{2t-1} and Ψ_t (Exchange rate values). The results for the test statistic model Γ_{2t} (INDF) is very significant with p-value < 0.0001 and R-square 0.9744 this means that 97.44% variation of INDF can be accounted for variables lag Γ_{1t-1} , Γ_{2t-1} and Ψ_t (Exchange rate values). With high values of R-squares, this indicates that the VARX(1,0) model is fit with the data.

Table 5. Univariate Model ANOVA Diagnostics checks for the parameters used in model

Variable	R-Square	Standard Deviation	F Value	Pr > F
ICBP	0.9802	159.13415	21481.8	<.0001
INDF	0.9744	133.05888	16552.0	<.0001

Impulse Response Function

In this study, IRF is used to describe how economics reacts to exogenous impulses, commonly referred to by economists as shock or shocks and models in the context of VAR. Figure 4. Shows IRF shock in the exchange rate. A standard deviation of the exchange rate causes the ICBP to respond negatively for about 100 days and the minimum effect (first day) with a value of around -0.01 but after that it shifts to zero (stable condition) to around 770 days. Whereas the exchange rate causes INDF to respond negatively for about 150 days and after that it is in a stable condition which is in the 0 to 3 years period.

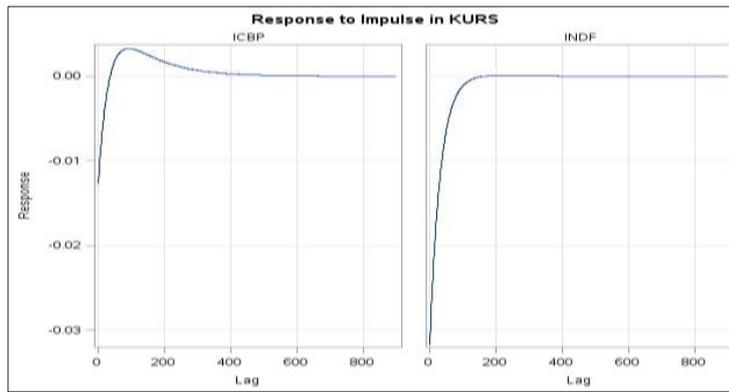


Figure 3. Impulse Response Function in Exchange Rate

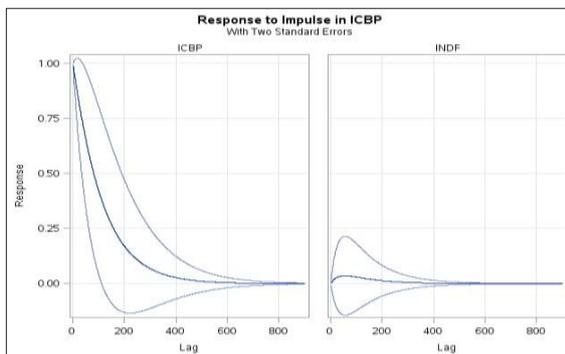


Figure 4. Impulse Response Function in ICBP

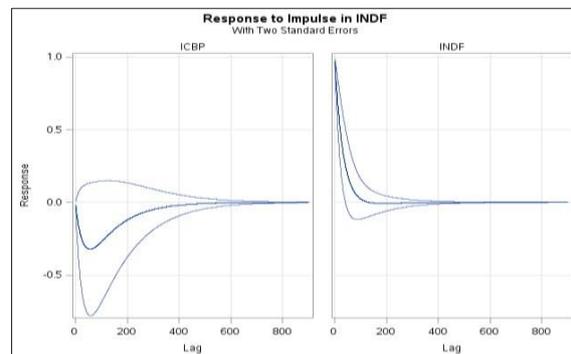


Figure 5. Impulse Response Function in INDF

Figure 4. Shows IRF shock at ICBP with one standard deviation at ICBP causing ICBP to respond positively and have significance for about 3 months, whereas from the third to the 14th month the response moves to zero (stable condition). Thus, stable conditions were reached until the 14th month onwards. Behavior at confidence intervals between the third and 14th months is very interesting when there is high volatility. Impulses in ICBP appear to have an effect on INDF volatility. The IRF plot for INDF shows that INDF responded positively about 7 months ago to stabilize around zero when volatility is high up to a year after the ICBP shock, which shows that the closing price of the INDF stock fluctuated within the year after the ICBP shock. And Figure 5. Shows IRF shock at INDF with one standard deviation at INDF causing ICBP to respond positively for about 14 months, after which it returned to a stable condition, which is at 0. From the behaviour of the confidence interval on the ICBP plot, it can be observed that the volatility is very high. Therefore, it can be concluded that in this horizon, closing prices after the INDF shock fluctuate significantly. The impact of impulses in INDF causes INDF to respond positively and has significance for about 3 months then the response moves to 0 (stable condition). Thus, stable conditions were achieved until the following months.

Granger Causality

In Table 6. Test 2 shows the p-value of 0.1916 which means that ICBP only affects itself and does not affect INDF and so does Test 5 show that even INDF does not affect ICBP and only affects itself with p-value 0.4157. And in Test 7. Obtained significant test results namely the ICBP variable and the INDF variable is influenced by the exchange rate with p-value 0.0047 (<0.05).

Table 6. Granger Causality Wald Test

Test Group	DF	Chi-Square	Pr > ChiSq
2 Group 1 variables: ICBP Group 2 variables: INDF	1	1.71	0.1916
5 Group 1 variables: INDF Group 2 variables: ICBP	1	0.66	0.4157
7 Group 1 variables: KURS Group 2 variables: ICBP INDF	2	10.74	0.0047

Forecasting

Forecasting is a process that allows the estimation of unknown future values that are used to predict forecast values in the time series data. In this study, the VARX (1,0) model was used to predict 30 values from ICBP and INDF data. Figure 6. Shows that the VARX (1,0) model for ICBP is very compatible with the original data. The circle represents the original data and the lines describe the model. Below is a predictive value with a 95% confidence interval. Accordingly, ICBP prediction data for the next 30 days appear to be increasing slightly.

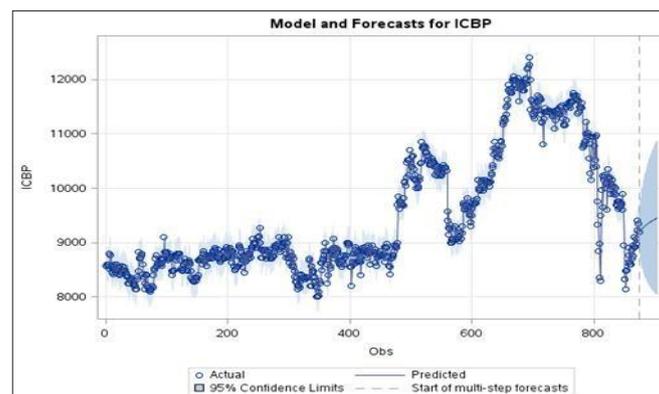


Figure 6. Prediction and Forecasting of ICBP

In Figure 7. shows that the VARX(1,0) model for INDF is also very close to the original data. As for the INDF data, the circle represents the original data and the lines describe the model. Below is a predictive value with a 95% confidence interval. Thus, ICBP prediction data for the next 30 days seem to form an increasing trend.

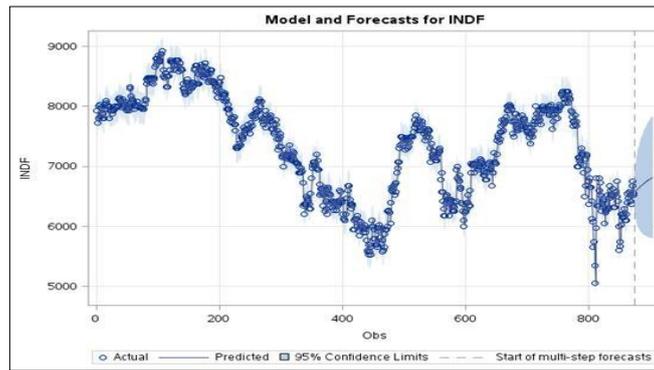


Figure 7. Prediction and Forecasting of INDF

Conclusion

Based on the results of the analysis of the relationship between endogenous variables namely ICBP and INDF and exogenous variables namely exchange rates, the best model for the relationship between these variables is the VARX(1,0) model. And univariate model obtained from the VARX(1,0) model is very significant. Based on the results of the IRF analysis, it can be concluded that if there is a shock in the exchange rate, then and through the Granger Causality test the results show that the exchange rate affects the ICBP and INDF. The univariate model for forecasting is very significant and the predictive value is very close to observation. This shows that this model is very reliable to be used for forecasting, forecasting results for the next 30 days do not fluctuate too much, but the confidence interval is greater as the period of prediction gets farther.

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VARIATIONAL HOMOTOPY PERTURBATION METHOD FOR SOLVING HOMOGENEOUS LINEAR AND NONLINEAR PARTIAL DIFFERENTIAL EQUATION SYSTEM

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ABSTRACT

In this article, variational homotopy perturbation method is applied to solve homogeneous partial differential equation systems. Variational homotopy perturbation method is developed by combining variational iteration method and homotopy perturbation method. Variational iteration method has an efficient process in solving a wide variety of equations and system of equations. Meanwhile, homotopy perturbation method yields a very rapid convergence of the solution series in the most cases. The developed method, variational homotopy perturbation method, took a full advantage of both methods. After this method is applied to homogeneous partial differential equation systems that have initial conditions, in this case, for partial differential equation systems with two and three variables, it is shown that the obtained results are equivalent to the results obtained by homotopy analysis method and variational iteration method.

INTRODUCTION

Partial differential equation can be encountered when a certain problem is related to physics and geometry if the function related is dependent on two or more than two variables. Complicated problem, such as problem in advanced physics, needs to be modelled into partial differential equation. But these partial differential equations are difficult to get their exact solutions, especially for the nonlinear ones. Nowadays, a lot of method have been developed to solve partial differential equation, whether it is analytic or numerical method.

In 1998, He suggested a method called homotopy perturbation method. This method yields a very rapid convergence of the solution series in the most cases. Usually, one iteration leads to high accuracy of the solution. This method is very effective and simple (Matinfar, 2009).

In 1999, He suggested another method called variational iteration method. This method uses an efficient process for a wide variety of scientific and engineering applications. This method gives rapidly convergent successive approximations of the exact solution. Variational iteration method is capable of greatly reducing the size of

calculation while still maintaining high accuracy of the numerical solution (Wazwaz, 2007).

Variational homotopy perturbation method is suggested by combining the variational iteration method and homotopy perturbation method. This method takes full advantage of both methods. This method is applied without any discretization, restrictive assumption, or transformation and is free from round-off errors. Unlike the method of separation variables that require initial and boundary conditions, the variational homotopy perturbation method provides an analytical solution by using the initial conditions only. This method works efficiently and the results so far are very reliable (Noor, 2008).

In the last few years, variational homotopy perturbation method had been used to solve a lot of scientific problems. Four of them are reaction-diffusion-convection problems (Daga, 2013), Burgers equation (Hendi, 2016), partial differential problem in fluid mechanics (Allahviranloo, 2014), and Fisher equation (Matinfar, 2010). The solved problems in all these four articles are a partial differential equation. Hence, in this article, variational homotopy perturbation is applied to solve partial differential equation systems. Specifically, homogeneous linear and nonlinear partial differential equation system with two and three variables.

METHOD

In this section, some theories used in this article will be presented.

Homotopy Perturbation Method

Consider a general equation of the type,

$$L(u) = 0, \quad (1)$$

where L is any integral or differential operator. We define a convex homotopy $H(u, p)$ by

$$H(u, p) = (1 - p)F(u) + pL(u), \quad (2)$$

where $F(u)$ is a functional operator with known solutions v_0 , which can be obtained easily. It is clear that, for $H(u, p) = 0$, we have

$$H(u, 0) = F(u), \quad H(u, 1) = L(u). \quad (3)$$

This shows that $H(u, p)$ continuously traces an implicitly defined curve from a starting point $H(v_0, 0)$ to a solution function $H(f, 1)$. The embedding parameter $p \in [0, 1]$ can be considered as an expanding parameter. The homotopy perturbation method uses the homotopy parameter p as an embedding parameter to obtain

$$u = \sum_{i=0}^{\infty} p^i u_i = u_0 + pu_1 + p^2u_2 + p^3u_3 + \dots \quad (4)$$

If $p \rightarrow 1$, then (4) becomes the approximate solution of the form

$$f = \lim_{p \rightarrow 1} u = \sum_{i=0}^{\infty} u_i. \quad (5)$$

It is well known that series (4) is convergent for most of the cases and also the rate of convergence is dependent on $L(u)$. We assume (5) has a unique solution. The comparisons of like powers of p gives solutions of various orders.

Variational Iteration Method

Consider the following system of partial differential equation in an operator form:

$$\begin{aligned}
L_t(u) + R_1(u, v, w) + N_1(u, v, w) &= g_1, \\
L_t(v) + R_2(u, v, w) + N_2(u, v, w) &= g_2, \\
L_t(w) + R_3(u, v, w) + N_3(u, v, w) &= g_3,
\end{aligned}$$

(6)

with initial conditions

$$\begin{aligned}
u(x, 0) &= f_1(x), \\
v(x, 0) &= f_2(x), \\
w(x, 0) &= f_3(x),
\end{aligned}$$

(7)

where L_t is a differential operator, R_j , $1 \leq j \leq 3$, and N_j , $1 \leq j \leq 3$ are linear and nonlinear operator respectively, and g_1 , g_2 , g_3 are the source term. According to variational iteration method, we can construct a correct functional for system of equation as follows:

$$\begin{aligned}
u_{n+1}(x, t) &= u_n(x, t) + \int_0^t \lambda_1(Lu_n(\xi) + R_1(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) + N_1(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) - g_1(\xi)) d\xi, \\
v_{n+1}(x, t) &= v_n(x, t) + \int_0^t \lambda_2(Lu_n(\xi) + R_2(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) + N_2(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) - g_2(\xi)) d\xi, \\
w_{n+1}(x, t) &= w_n(x, t) + \int_0^t \lambda_3(Lu_n(\xi) + R_3(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) + N_3(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) - g_3(\xi)) d\xi, \quad (8)
\end{aligned}$$

where λ_j , $1 \leq j \leq 3$ is a Lagrange multiplier, which can be identified optimally via variational iteration method. In this method, it is required first to determine the Lagrange multiplier λ optimally. The successive approximation $u_{n+1}(x, t)$, $v_{n+1}(x, t)$, $w_{n+1}(x, t)$, $n \geq 0$ of the solution $u(x, t)$, $v(x, t)$, $w(x, t)$ will be readily obtained upon using the determined Lagrange multiplier and any selective function u_0, v_0, w_0 , consequently, the solution is given by

$$\begin{aligned}
u(x, t) &= \lim_{n \rightarrow \infty} u_n(x, t), \\
v(x, t) &= \lim_{n \rightarrow \infty} v_n(x, t), \\
w(x, t) &= \lim_{n \rightarrow \infty} w_n(x, t).
\end{aligned}$$

(9)

Variational Homotopy Perturbation Method

Consider the following system of partial differential equation in an operator form:

$$\begin{aligned}
L_t(u) + R_1(u, v, w) + N_1(u, v, w) &= g_1, \\
L_t(v) + R_2(u, v, w) + N_2(u, v, w) &= g_2, \\
L_t(w) + R_3(u, v, w) + N_3(u, v, w) &= g_3,
\end{aligned}$$

(10)

where L_t is a differential operator, R_j , $1 \leq j \leq 3$, and N_j , $1 \leq j \leq 3$ are linear and nonlinear operator respectively, and g_1 , g_2 , g_3 are the source term. According to variational iteration method, we can construct a correct functional for system of equation as follows:

$$\begin{aligned}
u_{n+1}(x, t) &= u_n(x, t) + \int_0^t \lambda_1(Lu_n(\xi) + R_1(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) + N_1(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) - g_1(\xi)) d\xi, \\
v_{n+1}(x, t) &= v_n(x, t) + \int_0^t \lambda_2(Lu_n(\xi) + R_2(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) + N_2(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) - g_2(\xi)) d\xi, \\
w_{n+1}(x, t) &= w_n(x, t) + \int_0^t \lambda_3(Lu_n(\xi) + R_3(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) + N_3(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) - g_3(\xi)) d\xi, \quad (11)
\end{aligned}$$

where λ_j , $1 \leq j \leq 3$ is a Lagrange multiplier, which can be identified optimally via variational iteration method. Now, we apply the homotopy perturbation method,

$$\sum_{n=0}^{\infty} p^{(n)} u_n(x, t) = u_0(x, t) + p \int_0^t \lambda_1 (Lu_n(\xi) + R_1(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) + N_1(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n)) d\xi - \int_0^t \lambda_1 (g_1(\xi)) d\xi,$$

$$\sum_{n=0}^{\infty} p^{(n)} v_n(x, t) = v_0(x, t) + p \int_0^t \lambda_2 (Lv_n(\xi) + R_2(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) + N_2(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n)) d\xi - \int_0^t \lambda_2 (g_2(\xi)) d\xi,$$

$$\sum_{n=0}^{\infty} p^{(n)} w_n(x, t) = w_0(x, t) + p \int_0^t \lambda_3 (Lw_n(\xi) + R_3(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) + N_3(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n)) d\xi - \int_0^t \lambda_3 (g_3(\xi)) d\xi.$$

(12)

A comparison of like powers of p gives solutions of various orders.

Then, variational homotopy perturbation method is applied to homogeneous linear and nonlinear partial differential equation systems. The summary of the steps is as follows:

1. Construct the correct functional of each equation in the partial differential equation systems.
2. Apply the homotopy perturbation method into equations obtained by step (1).
3. Equate the coefficients of the terms with the identical power of p from the equations obtained by step (2).
4. Substitute the results into solution series, hence the solutions of the equation systems are obtained.

RESULTS AND DISCUSSION

In this section, variational homotopy perturbation method is applied to solve homogeneous linear and nonlinear partial differential equation system with two and three variables.

Variational Homotopy Perturbation on Homogeneous Linear Equation System

Given homogeneous linear equation system,

$$u_t - v_x + (u + v) = 0, \quad (13)$$

$$v_t - u_x + (u + v) = 0, \quad (14)$$

with the initial conditions

$$u(x, 0) = \sinh x, \quad v(x, 0) = \cosh x \quad (15)$$

(Bataineh, 2008). To solve system (13) - (15), we choose the initial approximations

$$u_0(x, 0) = \sinh x, \quad v_0(x, 0) = \cosh x. \quad (16)$$

Based on variational iteration method, we can construct correct functionals of system (13) - (14) as follow,

$$u_{n+1}(x, t) = u_n(x, t) + \int_0^t \lambda_1 (Lu_n(\xi) + N_1(\tilde{u}_n, \tilde{v}_n) - g_1(\xi)) \delta\xi, \quad (17)$$

$$u_{n+1}(x, t) = u_n(x, t)$$

$$+ \int_0^t \lambda_1 \left(\frac{\partial u_n(x, \xi)}{\partial \xi} - \frac{\partial v_n(x, \xi)}{\partial x} + \tilde{u}_n(x, \xi) + \tilde{v}_n(x, \xi) \right) \delta \xi; \quad (18)$$

$$v_{n+1}(x, t) = v_n(x, t) + \int_0^t \lambda_2 (Lv_n(\xi) + N_2(\tilde{u}_n, \tilde{v}_n) - g_2(\xi)) \delta \xi, \quad (19)$$

$$v_{n+1}(x, t) = v_n(x, t) + \int_0^t \lambda_2 \left(\frac{\partial v_n(x, \xi)}{\partial \xi} - \frac{\partial u_n(x, \xi)}{\partial x} + \tilde{u}_n(x, \xi) + \tilde{v}_n(x, \xi) \right) \delta \xi; \quad (20)$$

This yields the stationary conditions

$$1 + \lambda_1 = 0, \quad \lambda_1'(\xi = t) = 0,$$

$$1 + \lambda_2 = 0, \quad \lambda_2'(\xi = t) = 0.$$

As a result, we find $\lambda_1 = \lambda_2 = -1$.

Substituting these values of the Lagrange multipliers into the functionals (18) and (20) gives the following iteration formulas.

$$u_{n+1}(x, t) = u_n(x, t) - \int_0^t \left(\frac{\partial u_n(x, \xi)}{\partial \xi} - \frac{\partial v_n(x, \xi)}{\partial x} + \tilde{u}_n(x, \xi) + \tilde{v}_n(x, \xi) \right) \delta \xi; \quad (21)$$

$$v_{n+1}(x, t) = v_n(x, t) - \int_0^t \left(\frac{\partial v_n(x, \xi)}{\partial \xi} - \frac{\partial u_n(x, \xi)}{\partial x} + \tilde{u}_n(x, \xi) + \tilde{v}_n(x, \xi) \right) \delta \xi; \quad (22)$$

where $n \geq 0$. Applying the homotopy perturbation method to (21) – (22), we have

$$\sum_{n=0}^{\infty} p^n u_n = u_0(x, t) - p \int_0^t \left(\left(\sum_{n=0}^{\infty} p^n u_n \right)_{\xi} - \left(\sum_{n=0}^{\infty} p^n v_n \right)_x + \left(\sum_{n=0}^{\infty} p^n u_n \right) + \left(\sum_{n=0}^{\infty} p^n v_n \right) \right) \delta \xi, \quad (23)$$

$$u_0 + pu_1 + p^2u_2 + \dots = u_0(x, t) - p \int_0^t \left(\left(\frac{\partial u_0(x, \xi)}{\partial \xi} - \frac{\partial v_0(x, \xi)}{\partial x} + \tilde{u}_0(x, \xi) + \tilde{v}_0(x, \xi) \right) + p \left(\frac{\partial u_1(x, \xi)}{\partial \xi} - \frac{\partial v_1(x, \xi)}{\partial x} + \tilde{u}_1(x, \xi) + \tilde{v}_1(x, \xi) \right) + p^2 \left(\frac{\partial u_2(x, \xi)}{\partial \xi} - \frac{\partial v_2(x, \xi)}{\partial x} + \tilde{u}_2(x, \xi) + \tilde{v}_2(x, \xi) \right) + \dots \right) \delta \xi; \quad (24)$$

$$\sum_{n=0}^{\infty} p^n v_n = v_0(x, t) - p \int_0^t \left(\left(\sum_{n=0}^{\infty} p^n v_n \right)_{\xi} - \left(\sum_{n=0}^{\infty} p^n u_n \right)_x + \left(\sum_{n=0}^{\infty} p^n u_n \right) + \left(\sum_{n=0}^{\infty} p^n v_n \right) \right) \delta \xi, \quad (25)$$

$$v_0 + pv_1 + p^2v_2 + \dots = v_0(x, t) - p \int_0^t \left(\left(\frac{\partial v_0(x, \xi)}{\partial \xi} - \frac{\partial u_0(x, \xi)}{\partial x} + \tilde{u}_0(x, \xi) + \tilde{v}_0(x, \xi) \right) + p \left(\frac{\partial v_1(x, \xi)}{\partial \xi} - \frac{\partial u_1(x, \xi)}{\partial x} + \tilde{u}_1(x, \xi) + \tilde{v}_1(x, \xi) \right) + p^2 \left(\frac{\partial v_2(x, \xi)}{\partial \xi} - \frac{\partial u_2(x, \xi)}{\partial x} + \tilde{u}_2(x, \xi) + \tilde{v}_2(x, \xi) \right) + \dots \right) \delta \xi. \quad (26)$$

Equating the coefficients of the terms with the identical powers of p , we get p^0 : $u_0(x, t) = \sinh x$;

$$\begin{aligned}
 &v_0(x, t) = \cosh x. \\
 p^1: &u_1(x, t) = -t \cosh x; \\
 &v_1(x, t) = -t \sinh x. \\
 p^2: &u_2(x, t) = \frac{t^2}{2!} \sinh x; \\
 &v_2(x, t) = \frac{t^2}{2!} \cosh x. \\
 p^3: &u_3(x, t) = -\frac{t^3}{3!} \cosh x; \\
 &v_3(x, t) = -\frac{t^3}{3!} \sinh x. \\
 p^4: &u_4(x, t) = \frac{t^4}{4!} \sinh x; \\
 &v_4(x, t) = -\frac{t^4}{4!} \cosh x. \\
 p^5: &u_5(x, t) = -\frac{t^5}{5!} \cosh x; \\
 &v_5(x, t) = -\frac{t^5}{5!} \sinh x.
 \end{aligned}$$

Then, the solution series of homotopy perturbation method is given by

$$u(x, t) = \sum_{n=0}^{\infty} p^n u_n(x, t) = u_0 + pu_1 + p^2u_2 + p^3u_3 + \dots \quad (27)$$

$$v(x, t) = \sum_{n=0}^{\infty} p^n v_n(x, t) = v_0 + pv_1 + p^2v_2 + p^3v_3 + \dots \quad (28)$$

By setting $p = 1$, the solution of the equation system can be written as the following

$$u(x, t) = \sinh x \left(1 + \frac{t^2}{2!} + \frac{t^4}{4!} + \dots \right) - \cosh x \left(t + \frac{t^3}{3!} + \frac{t^5}{5!} + \dots \right); \quad (29)$$

$$v(x, t) = \cosh x \left(1 + \frac{t^2}{2!} + \frac{t^4}{4!} + \dots \right) - \sinh x \left(t + \frac{t^3}{3!} + \frac{t^5}{5!} + \dots \right); \quad (30)$$

which will converge to the exact solution, $u(x, t) = \sinh(x - t)$ and $v(x, t) = \cosh(x - t)$, that matches the solution obtained by homotopy analysis method (Bataineh, 2008) and variational iteration method (Wazwaz, 2007).

Variational Homotopy Perturbation on Homogeneous Nonlinear Equation System

Given homogeneous nonlinear equation system,

$$u_t + u_x v_x + u_y v_y + u = 0, \quad (31)$$

$$v_t + v_x w_x - v_y w_y - v = 0, \quad (32)$$

$$w_t + w_x u_x + w_y u_y - w = 0, \quad (33)$$

with the initial conditions

$$u(x, y, 0) = e^{x+y}, \quad v(x, y, 0) = e^{x-y}, \quad w(x, y, 0) = e^{-x+y} \quad (34)$$

(Bataineh, 2008). To solve system (31) - (34), we choose the initial approximations

$$u_0(x, y, 0) = e^{x+y}, \quad v_0(x, y, 0) = e^{x-y}, \quad w_0(x, y, 0) = e^{-x+y}. \quad (35)$$

Based on variational iteration method, we can construct correct functionals of system (31) - (33) as follow,

$$u_{n+1}(x, y, t) = u_n(x, y, t) + \int_0^t \lambda_1 (Lu_n(\xi) + N_1(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) - g_1(\xi)) \delta \xi, \quad (36)$$

$$u_{n+1}(x, y, t) = u_n(x, y, t) + \int_0^t \lambda_1 \left(\frac{\partial u_n(x, y, \xi)}{\partial \xi} + \frac{\partial u_n(x, y, \xi)}{\partial x} \cdot \frac{\partial v_n(x, y, \xi)}{\partial x} + \frac{\partial u_n(x, y, \xi)}{\partial y} \cdot \frac{\partial v_n(x, y, \xi)}{\partial y} - \tilde{u}_n(x, y, \xi) \right) \delta \xi; \quad (37)$$

$$v_{n+1}(x, y, t) = v_n(x, y, t) + \int_0^t \lambda_2 (Lv_n(\xi) + N_2(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) - g_2(\xi)) \delta \xi, \quad (38)$$

$$v_{n+1}(x, y, t) = v_n(x, y, t) + \int_0^t \lambda_2 \left(\frac{\partial v_n(x, y, \xi)}{\partial \xi} + \frac{\partial v_n(x, y, \xi)}{\partial x} \cdot \frac{\partial w_n(x, y, \xi)}{\partial x} - \frac{\partial v_n(x, y, \xi)}{\partial y} \cdot \frac{\partial w_n(x, y, \xi)}{\partial y} - \tilde{v}_n(x, y, \xi) \right) \delta \xi; \quad (39)$$

$$w_{n+1}(x, y, t) = w_n(x, y, t) + \int_0^t \lambda_3 (Lv_n(\xi) + N_3(\tilde{u}_n, \tilde{v}_n, \tilde{w}_n) - g_3(\xi)) \delta \xi, \quad (40)$$

$$w_{n+1}(x, y, t) = w_n(x, y, t) + \int_0^t \lambda_3 \left(\frac{\partial w_n(x, y, \xi)}{\partial \xi} + \frac{\partial w_n(x, y, \xi)}{\partial x} \cdot \frac{\partial u_n(x, y, \xi)}{\partial x} + \frac{\partial w_n(x, y, \xi)}{\partial y} \cdot \frac{\partial u_n(x, y, \xi)}{\partial y} - \tilde{w}_n(x, y, \xi) \right) \delta \xi. \quad (41)$$

This yields the stationary conditions

$$1 + \lambda_1 = 0, \quad \lambda'_1(\xi = t) = 0,$$

$$1 + \lambda_2 = 0, \quad \lambda'_2(\xi = t) = 0.$$

$$1 + \lambda_3 = 0, \quad \lambda'_3(\xi = t) = 0.$$

As a result, we find $\lambda_1 = \lambda_2 = \lambda_3 = -1$.

Substituting these values of the Lagrange multipliers into the functionals (36), (38) and (40) gives the following iteration formulas.

$$u_{n+1}(x, y, t) = u_n(x, y, t) - \int_0^t \left(\frac{\partial u_n(x, y, \xi)}{\partial \xi} + \frac{\partial u_n(x, y, \xi)}{\partial x} \cdot \frac{\partial v_n(x, y, \xi)}{\partial x} + \frac{\partial u_n(x, y, \xi)}{\partial y} \cdot \frac{\partial v_n(x, y, \xi)}{\partial y} - \tilde{u}_n(x, y, \xi) \right) \delta \xi; \quad (42)$$

$$v_{n+1}(x, y, t) = v_n(x, y, t) - \int_0^t \left(\frac{\partial v_n(x, y, \xi)}{\partial \xi} + \frac{\partial v_n(x, y, \xi)}{\partial x} \cdot \frac{\partial w_n(x, y, \xi)}{\partial x} - \frac{\partial v_n(x, y, \xi)}{\partial y} \cdot \frac{\partial w_n(x, y, \xi)}{\partial y} - \tilde{v}_n(x, y, \xi) \right) \delta \xi; \quad (43)$$

$$w_{n+1}(x, y, t) = w_n(x, y, t) - \int_0^t \left(\frac{\partial w_n(x, y, \xi)}{\partial \xi} + \frac{\partial w_n(x, y, \xi)}{\partial x} \cdot \frac{\partial u_n(x, y, \xi)}{\partial x} + \frac{\partial w_n(x, y, \xi)}{\partial y} \cdot \frac{\partial u_n(x, y, \xi)}{\partial y} - \tilde{w}_n(x, y, \xi) \right) \delta \xi; \quad (44)$$

where $n \geq 0$. Applying the homotopy perturbation method to (42) – (44), we have

$$\begin{aligned} & \sum_{n=0}^{\infty} p^n u_n = \\ & u_0(x, y, t) - p \int_0^t \left((\sum_{n=0}^{\infty} p^n u_n)_\xi + (\sum_{n=0}^{\infty} p^n u_n)_x (\sum_{n=0}^{\infty} p^n v_n)_x + (\sum_{n=0}^{\infty} p^n u_n)_y (\sum_{n=0}^{\infty} p^n v_n)_y + \right. \\ & \left. (\sum_{n=0}^{\infty} p^n u_n) \right) \delta \xi \end{aligned} \quad (45)$$

$$u_0 + pu_1 + p^2u_2 + \dots = u_0(x, y, t) - p \int_0^t \left(\left(\frac{\partial u_0(x, y, \xi)}{\partial \xi} + \frac{\partial u_0(x, y, \xi)}{\partial x} \cdot \frac{\partial v_0(x, y, \xi)}{\partial x} + \frac{\partial u_0(x, y, \xi)}{\partial y} \cdot \frac{\partial v_0(x, y, \xi)}{\partial y} + \tilde{u}_0(x, y, \xi) \right) + p \left(\frac{\partial u_1(x, y, \xi)}{\partial \xi} + \frac{\partial u_1(x, y, \xi)}{\partial x} \cdot \frac{\partial v_1(x, y, \xi)}{\partial x} + \frac{\partial u_1(x, y, \xi)}{\partial y} \cdot \frac{\partial v_1(x, y, \xi)}{\partial y} + \tilde{u}_1(x, y, \xi) \right) + p^2 \left(\frac{\partial u_2(x, y, \xi)}{\partial \xi} + \frac{\partial u_2(x, y, \xi)}{\partial x} \cdot \frac{\partial v_2(x, y, \xi)}{\partial x} + \frac{\partial u_2(x, y, \xi)}{\partial y} \cdot \frac{\partial v_2(x, y, \xi)}{\partial y} + \tilde{u}_2(x, y, \xi) \right) + \dots \right) \delta \xi; \quad (46)$$

$$\sum_{n=0}^{\infty} p^n v_n = v_0(x, y, t) - p \int_0^t \left((\sum_{n=0}^{\infty} p^n v_n)_\xi + (\sum_{n=0}^{\infty} p^n v_n)_x (\sum_{n=0}^{\infty} p^n w_n)_x - (\sum_{n=0}^{\infty} p^n v_n)_y (\sum_{n=0}^{\infty} p^n w_n)_y - (\sum_{n=0}^{\infty} p^n v_n) \right) \delta \xi \quad (47)$$

$$v_0 + pv_1 + p^2v_2 + \dots = v_0(x, y, t) - p \int_0^t \left(\left(\frac{\partial v_0(x, y, \xi)}{\partial \xi} + \frac{\partial v_0(x, y, \xi)}{\partial x} \cdot \frac{\partial w_0(x, y, \xi)}{\partial x} - \frac{\partial v_0(x, y, \xi)}{\partial y} \cdot \frac{\partial w_0(x, y, \xi)}{\partial y} - \tilde{v}_0(x, y, \xi) \right) + p \left(\frac{\partial v_1(x, y, \xi)}{\partial \xi} + \frac{\partial v_1(x, y, \xi)}{\partial x} \cdot \frac{\partial w_1(x, y, \xi)}{\partial x} - \frac{\partial v_1(x, y, \xi)}{\partial y} \cdot \frac{\partial w_1(x, y, \xi)}{\partial y} - \tilde{v}_1(x, y, \xi) \right) + p^2 \left(\frac{\partial v_2(x, y, \xi)}{\partial \xi} + \frac{\partial v_2(x, y, \xi)}{\partial x} \cdot \frac{\partial w_2(x, y, \xi)}{\partial x} - \frac{\partial v_2(x, y, \xi)}{\partial y} \cdot \frac{\partial w_2(x, y, \xi)}{\partial y} - \tilde{v}_2(x, y, \xi) \right) + \dots \right) \delta \xi \quad (48)$$

$$\sum_{n=0}^{\infty} p^n w_n = w_0(x, y, t) - p \int_0^t \left((\sum_{n=0}^{\infty} p^n w_n)_\xi + (\sum_{n=0}^{\infty} p^n w_n)_x (\sum_{n=0}^{\infty} p^n u_n)_x + (\sum_{n=0}^{\infty} p^n w_n)_y (\sum_{n=0}^{\infty} p^n u_n)_y - (\sum_{n=0}^{\infty} p^n w_n) \right) \delta \xi \quad (49)$$

$$w_0 + pw_1 + p^2w_2 + \dots = w_0(x, y, t) - p \int_0^t \left(\left(\frac{\partial w_0(x, y, \xi)}{\partial \xi} + \frac{\partial w_0(x, y, \xi)}{\partial x} \cdot \frac{\partial u_0(x, y, \xi)}{\partial x} - \frac{\partial w_0(x, y, \xi)}{\partial y} \cdot \frac{\partial u_0(x, y, \xi)}{\partial y} - \tilde{w}_0(x, y, \xi) \right) + p \left(\frac{\partial w_1(x, y, \xi)}{\partial \xi} + \frac{\partial w_1(x, y, \xi)}{\partial x} \cdot \frac{\partial u_1(x, y, \xi)}{\partial x} - \frac{\partial w_1(x, y, \xi)}{\partial y} \cdot \frac{\partial u_1(x, y, \xi)}{\partial y} - \tilde{w}_1(x, y, \xi) \right) + p^2 \left(\frac{\partial w_2(x, y, \xi)}{\partial \xi} + \frac{\partial w_2(x, y, \xi)}{\partial x} \cdot \frac{\partial u_2(x, y, \xi)}{\partial x} - \frac{\partial w_2(x, y, \xi)}{\partial y} \cdot \frac{\partial u_2(x, y, \xi)}{\partial y} - \tilde{w}_2(x, y, \xi) \right) + \dots \right) \delta \xi \quad (50)$$

Equating the coefficients of the terms with the identical powers of p , we get

$$\begin{aligned} p^0: \quad & u_0(x, y, t) = e^{x+y}; \\ & v_0(x, y, t) = e^{x-y}; \\ & w_0(x, y, t) = e^{-x+y}. \\ p^1: \quad & u_1(x, y, t) = -te^{x+y}; \\ & v_1(x, y, t) = te^{x-y}; \\ & w_1(x, y, t) = te^{-x+y}. \\ p^2: \quad & u_2(x, y, t) = \frac{t^2 e^{x+y}}{2!}; \end{aligned}$$

$$\begin{aligned}
 v_2(x, y, t) &= \frac{t^2 e^{x-y}}{2!}; \\
 w_2(x, y, t) &= \frac{t^2 e^{-x+y}}{2!}. \\
 p^3: \quad u_3(x, y, t) &= -\frac{t^3 e^{x+y}}{3!}; \\
 v_3(x, y, t) &= \frac{t^3 e^{x-y}}{3!}; \\
 w_3(x, y, t) &= \frac{t^3 e^{-x+y}}{3!}. \\
 p^4: \quad u_4(x, y, t) &= \frac{t^4 e^{x+y}}{4!}; \\
 v_4(x, y, t) &= \frac{t^4 e^{x-y}}{4!}; \\
 w_4(x, y, t) &= \frac{t^4 e^{-x+y}}{4!}. \\
 p^5: \quad u_5(x, y, t) &= -\frac{t^5 e^{x+y}}{5!}; \\
 v_5(x, y, t) &= \frac{t^5 e^{x-y}}{5!}; \\
 w_5(x, y, t) &= \frac{t^5 e^{-x+y}}{5!}.
 \end{aligned}$$

Then, the solution series of homotopy perturbation method is given by

$$u(x, t) = \sum_{n=0}^{\infty} p^n u_n(x, t) = u_0 + pu_1 + p^2u_2 + p^3u_3 + \dots; \quad (51)$$

$$v(x, t) = \sum_{n=0}^{\infty} p^n v_n(x, t) = v_0 + pv_1 + p^2v_2 + p^3v_3 + \dots \quad (52)$$

$$w(x, y, t) = \sum_{n=0}^{\infty} p^n w_n(x, y, t) = w_0 + pw_1 + p^2w_2 + p^3w_3 + \dots \quad (53)$$

By setting $p = 1$, the solution of the equation system can be written as the following

$$u(x, y, t) = e^{x+y} \left(1 - t + \frac{t^2}{2!} - \frac{t^3}{3!} + \frac{t^4}{4!} - \frac{t^5}{5!} + \dots \right); \quad (54)$$

$$v(x, y, t) = e^{x-y} \left(1 + t + \frac{t^2}{2!} + \frac{t^3}{3!} + \frac{t^4}{4!} + \frac{t^5}{5!} + \dots \right); \quad (55)$$

$$w(x, y, t) = e^{-x+y} \left(1 + t + \frac{t^2}{2!} + \frac{t^3}{3!} + \frac{t^4}{4!} + \frac{t^5}{5!} + \dots \right); \quad (56)$$

which will converge to the exact solution, $u(x, y, t) = e^{x+y-t}$; $v(x, y, t) = e^{x-y+t}$ and $w(x, y, t) = e^{-x+y+t}$, that matches the solution obtained by homotopy analysis method (Bataineh, 2008) and variational iteration method (Wazwaz, 2007).

CONCLUSIONS AND SUGGESTIONS

In this article, variational homotopy perturbation on homogeneous linear and nonlinear partial differential equation system with two and three variables have been applied. Based on the results obtained, the solutions match the solution obtained by homotopy analysis method (Bataineh, 2008) and variational iteration method (Wazwaz, 2007). From the previous sections, it can be concluded that variational homotopy perturbation method gives the solution by using the initial conditions only. Besides that, this method is capable of reducing the computational work while still maintaining the high accuracy of the result.

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APPLICATION OF COMPOST TEA AND COCOPEAT MEDIA PROMOTED GROWTH OF RED SPINACH (*Amaranthus tricolor* L.)

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ABSTRAK

Compost tea menjadi sumber unsur hara tambahan yang mudah di manfaatkan oleh tanaman bersamaan dengan penyerapan air sehingga dapat memperbaiki pertumbuhan tanaman. Selain unsur hara, media tanam juga berperan penting dalam mendukung pertumbuhan tanaman. *Cocopeat* menjadi salah satu komposisi media tanam yang baik karena mampu mengikat air dan hara tanah dengan membentuk pori penyimpanan, sehingga nutrisi di dalam tanah tidak mudah larut. Tujuan penelitian ini adalah untuk mengetahui pengaruh pemberian *Compost tea* yang terinduksi inokulum fungi lignoselulolitik pada media tanam *cocopeat* terhadap pertumbuhan tanaman bayam merah (*Amaranthus tricolor* L.) serta pengaruh interaksi antara *compost tea* dan perbandingan media tanam *cocopeat* : tanah yang terbaik dalam meningkatkan pertumbuhan tanaman bayam merah. Penelitian ini dilaksanakan pada bulan Mei sampai dengan Juli 2020 di *green house* Laboratorium Lapang Terpadu Fakultas Pertanian Universitas Lampung. Penelitian ini menggunakan Rancangan Acak Lengkap (RAL) Faktorial dengan faktor pertama (A) adalah *compost tea* dengan 2 taraf yaitu *compost tea* aerasi (ACT) A1 dan *compost tea* non aerasi A2, dan faktor kedua (B) adalah media tanam menggunakan 3 taraf yaitu (B1) *cocopeat* dan tanah (2:1), (B2) *cocopeat* dan tanah (1:1), (B3) *cocopeat* dan tanah (1:2) dengan kontrol hanya digunakan sebagai pembanding nilai rata-rata. Masing-masing unit perlakuan dilakukan sebanyak 4 kali pengulangan. Parameter yang diamati meliputi jumlah daun. Analisis ragam pada taraf nyata α 5%. Kemudian untuk melihat perbedaan antar perlakuan dengan uji Tukey pada taraf nyata α 5%. Hasil penelitian ini menunjukkan bahwa ACT dan media tanam *cocopeat* : tanah = 1:2, maupun interaksi keduanya menghasilkan nilai tertinggi dibandingkan dengan perlakuan yang lainnya.

Kata Kunci : *Amaranthus tricolor* L, *Cocopeat*, *Composttea*, Hara, Pertumbuhan.

ABSTRACT

Compost tea is a source of additional nutrients that are easily utilized by plants along with water absorption so that it can improve plant growth. Apart from nutrients, the planting medium also plays an important role in supporting plant growth. Cocopeat is a good growing media composition because it is able to bind water and soil nutrients by forming storage pores, so that the nutrients in the soil do not dissolve easily. The purpose of this study was to determine the effect of giving Compost tea induced by lignocellulolytic fungal inoculum on cocopeat growing media on the growth of red spinach (*Amaranthus tricolor* L.) and the effect of the interaction between compost tea and the ratio of cocopeat: the best soil to increase spinach plant growth. red. This research was carried out from May to July 2020 at the green house of the Integrated Field Laboratory of the Faculty of Agriculture, University of Lampung. This study used a Factorial Completely Randomized Design (CRD) with the first factor (A) is compost tea with 2 levels, namely compost tea aerated (ACT) A1 and compost tea non aerated A2, and the second factor (B) is planting media using 3 levels, namely (B1) cocopeat and soil (2: 1), (B2) cocopeat and soil (1: 1), (B3) cocopeat and soil (1: 2) with control were only used as a comparison of the average value. Each treatment unit was carried out. as much as 4 repetitions. The parameters observed included the number of leaves. Analysis of variance at the significance level of α 5%. Then to see the difference between treatments with Tukey's test at the significant level of α 5%. The results of this study indicate that ACT and cocopeat growing media: soil = 1: 2, as well as the interaction of the two produce the highest value compared to other treatments.

Keywords: *Amaranthus tricolor* L, Cocopeat, Composttea, Hara, Growth.

PENDAHULUAN

Hasil penelitian Irawan *et al.* (2019) menunjukkan bahwa kompos seresah yang diberi inokulum fungi selulolitik *Aspergillus fumigatus* mampu meningkatkan pertumbuhan vegetatif tanaman cabai merah besar. *Trichoderma* sp. Adalah jenis fungi yang juga mampu mempercepat degradasi seresah, selain itu kompos yang dihasilkannya mampu menghambat patogen tanaman (Howell, 2003).

Salah satu bentuk pemanfaatan kompos pada tanaman adalah dalam bentuk teh kompos. Teh kompos adalah ekstrak air kompos mengandung nutrisi hara terlarut (Martin, 2015). Hasil penelitian Pant *et al.* (2012) menunjukkan bahwa teh kompos mampu meningkatkan kandungan P, K, Ca dan Mg serta pertumbuhan akar tanaman pak choi lebih tinggi dibandingkan dengan pemberian kompos dalam bentuk padat. Hasil penelitian Bria (2016) menunjukkan bahwa teh kompos dapat meningkatkan pertumbuhan tanaman bayam merah yang dilihat dari tinggi tanaman, diameter batang, dan berat segar.

Treder (2008) menjelaskan bahwa penambahan serbuk kelapa pada media tanam dapat meningkatkan pertumbuhan akar yang diikuti dengan peningkatan pertumbuhan, jumlah daun, dan jumlah kuncup bunga lily. Serbuk kelapa adalah serbuk serabut atau mesocarp kelapa yang memiliki kemampuan meningkatkan pori pada media tanam yang baik sebagai penyimpan air tanah dan mecegah pemadatan tanah. Cocopeat baik

digunakan sebagai media tanaman tunggal maupun sebagai komponen dari media tanam (Yau dan Murphy, 2000).

Bayam merah (*Amaranthus tricolor* L.) merupakan tanaman hortikultura yang bernilai ekonomis dan gizi yang tinggi. Selain memiliki warna yang menarik, bayam merah juga mengandung vitamin A, B, dan C, serta protein. Bayam merah juga mengandung Antosianin yang berfungsi sebagai antioksidan dan obat anemia (Tapilouw, 2006). Meskipun bayam merah sangat bermanfaat namun ketersediaannya di pasar masih jarang (Hendro, 2008). Dalam penelitian ini, bayam merah akan digunakan sebagai tanaman uji untuk mengetahui pengaruh pemanfaatan *compost tea* pada media tanam serbuk kelapa terhadap pertumbuhan tanaman bayam merah.

Metode penelitian

Penelitian ini dilaksanakan pada bulan Mei sampai dengan Juli 2020 di rumah kaca Laboratorium Lapang Terpadu Fakultas Pertanian Universitas Lampung. Analisis pertumbuhan dilakukan di Laboratorium Botani Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Lampung. Penelitian ini dilakukan secara faktorial menggunakan rancangan acak lengkap (RAL). Perlakuan yang digunakan dalam penelitian terdiri dari dua faktor. Faktor pertama (A) adalah teh kompos (aerasi dan non aerasi), Faktor kedua (B) adalah media tanam dengan 3 taraf campuran serbuk kelapa dan tanah dengan perbandingan 2:1, 1:1, dan 1:2. Pengamatan dilakukan pada hari setelah tanam (HST) 35 HST, 45 HST, dan 55 HST. Variabel yang diamati adalah jumlah daun. Masing-masing unit perlakuan diulang sebanyak 4 kali. Satu unit percobaan adalah satu tanaman. Data dianalisis ragam (ANARA) pada taraf nyata α 5%. Kemudian untuk melihat perbedaan antar perlakuan dilanjutkan dengan uji Beda Nyata menggunakan uji Tukey pada taraf nyata α 5%.

Pembuatan Teh kompos

Teh kompos dibuat dengan menggunakan modifikasi metode Girsheet *al.* (2018). Kompos padat yang terinduksi oleh fungi Selulolitik (*Aspergillus* sp.) dan Ligninolitik (*Trichoderma* sp.) diperoleh dari penelitian sebelumnya. Rasio pembuatan teh kompos yaitu 1 : 5 (kg : L) kompos dengan air. Teh kompos kemudian didiamkan selama 72 jam, disaring dan siap digunakan.

Persiapan Media dan penanaman

Tanah yang akan digunakan diayak terlebih dahulu, sebelum dicampur dengan serbuk kelapa dan dimasukkan ke dalam polybag dengan total 500 gram. Benih ditanam dalam polybag yang telah diisi media tanam dengan kedalaman 2-3 cm. Dalam 1 polybag ditanam 2 benih.

Perlakuan penyiraman

Sebanyak 150 ml teh kompos disiramkan perminggu pada waktu pagi hari bersama dengan jadwal penyiraman. Penyiraman tanaman dilakukan dengan menggunakan air secukupnya.

Pengamatan

pengamatan dilakukan untuk mengukur pertumbuhan tanaman. Pengamatan variabel pertumbuhan bayam merah dilakukan dengan metode Kogoya, (2018), yang di modifikasi pada tanaman berumur 35 HST, 45 HST, dan 55 HST. Pengamatan dilakukan dengan menghitung jumlah daun pada setiap helaian daun yang telah membuka sempurna pada setiap sampel.

HASIL DAN PEMBAHASAN

Hasil

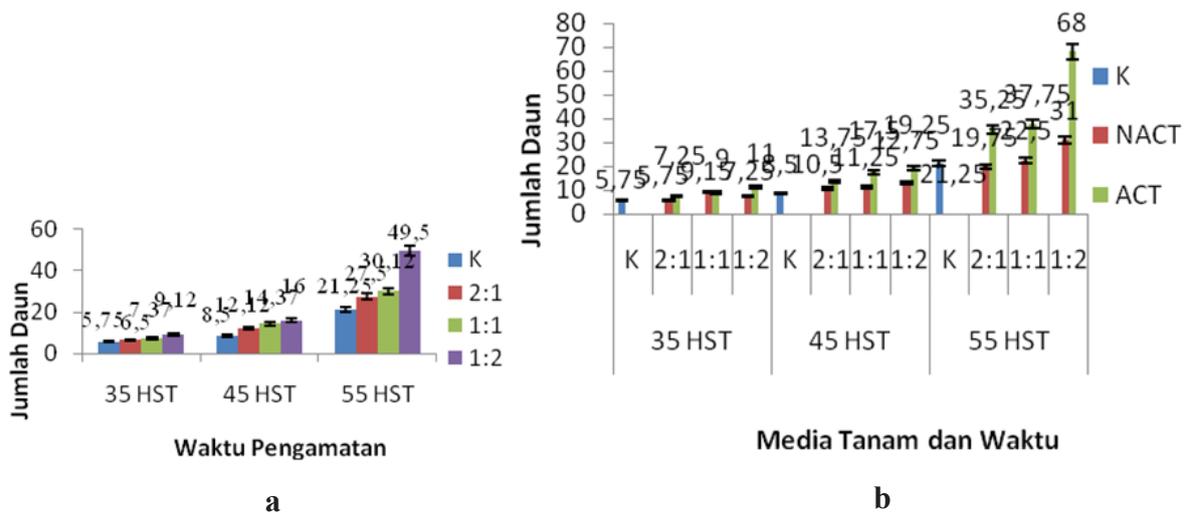
Hasil penelitian yang telah dilakukan menunjukkan jumlah daun pada perlakuan *compost tea* (A) maupun media tanam (B) termasuk interaksinya memberikan tanaman yang lebih tinggi dari perlakuan kontrol. Perlakuan *compost tea* aerasi (ACT) menghasilkan tanaman yang secara nyata lebih tinggi daripada tanaman yang diberi perlakuan *compost tea* non aerasi (NACT). Perlakuan media tanam yang menghasilkan tanaman tertinggi adalah media tanam dengan perbandingan *cocopeat* : tanah = 1:2 dan tinggi tanaman terendah adalah media tanam dengan perbandingan *cocopeat* : tanah = 2:1. Faktor perlakuan waktu menunjukkan pengaruh jumlah daun terbanyak dipanen pada tanaman berumur 55 hst (jumlah daun Tabel 1 Gambar 1).

1. Jumlah Daun

Tabel 1. Hasil uji tukey antar perlakuan teh kompos, media serbuk kelapa dan waktu pengamatan terhadap jumlah daun tanaman bayam merah.

Perlakuan	Jumlah Daun (Rata -Rata± SD)		
	35 HST	45 HST	55 HST
Media			
Serbuk kelapa + tanah			
2:1	6,50± 0,92 ^g	7,37± 1,84 ^{fg}	9,12± 2,16 ^f
1:1	12,12± 1,88 ^e	14,37± 3,42 ^{de}	16,00± 3,59 ^d
1:2	27,50± 8,59 ^c	30,12± 8,31 ^b	49,50± 19,94 ^a
Teh Kompos (Aerasi)			
Media serbuk kelapa + tanah			
2:1	7,25±0,50 ^{ij}	13,75±0,95 ^{fg}	35,25±32,00 ^b
1:1	9,00±0,81 ^{hij}	17,50±1,00 ^{ef}	37,75±1,25 ^b
1:2	11,00±0,81 ^{ghi}	19,25±0,95 ^{de}	68,00±0,81 ^a
Dengan teh kompos (Non Aerasi)			
Media serbuk kelapa + tanah			
2:1	5,75±0,50 ^j	10,50±0,57 ^{ghi}	19,75±1,70 ^{de}
1:1	9,15±0,50 ^j	11,25±0,50 ^{gh}	22,50±2,08 ^d
1:2	7,25±0,95 ^{ij}	12,75±0,95 ^{gh}	31,00±3,74 ^c

Keterangan: -Nilai-nilai dengan huruf yang sama pada kolom yang sama tidakberbeda nyata berdasarkan uji Tukey's pada taraf 5%.



Gambar 1. Respon jumlah daun tanaman bayam merah antara interaksi teh kopos dan media tanam serbuk kelapa pada waktu pengukuran yang berbeda. a, Pengaruh kombiasi antara perlakuan media tanam serbuk kelapa dan tanah, b. Pengaruh kombiasi antara perlakuan teh kompos dan media tanam pada waktu pengamatan yang berbeda.

Dilihat dari perlakuan Tabel 1 dan Gambar 1 yang menunjukkan interaksi antara *compost tea*, media tanam, dan waktu (A*B*C) yang memberikan perbedaan jumlah daun secara nyata.

PEMBAHASAN

Lebih tingginya nilai yang diperoleh dari perlakuan *compost tea* maupun media tanam daripada tanaman kontrol membuktikan bahwa pemberian *compost tea* terinduksi inokulum fungi selulolitik dan fungi ligninolitik dapat memacu pertumbuhan tanaman bayam merah terutama *compost tea* aerasi (ACT) yang di interaksikan dengan media tanam *cocopeat* : tanah = 1:2 pada jumlah daun. Hal ini diduga dalam kondisi yang cukup udara, mikroorganismenya dapat menguraikan senyawa kompleks di dalam kompos lebih optimal sehingga senyawa monomer sederhana yang tersedia dapat diserap tanaman lebih banyak. Menurut Isroi (2008), pemberian aerasi pada saat pembuatan *compost tea* berfungsi untuk memberi sirkulasi udara dalam media sehingga oksigen tersedia bagi mikroorganismenya.

Oleh karenanya, ACT memiliki unsur hara yang lebih banyak dan terlarut maksimal sehingga dapat dimanfaatkan optimum oleh tanaman sebagai sumber nutrisi untuk perbanyakan daun, ketahanan terhadap kelayuan, dan gugur daun. Hal ini sesuai dengan pendapat Manulang *etal.* (2014) yang mengatakan bahwa kelimpahan jumlah daun didukung oleh adanya unsur makro dan mikro pada pupuk kompos. Unsur yang berperan adalah magnesium dan kalium dimana kedua unsur ini saling mempengaruhi, sehingga daun-daun yang ada pada tanaman cabai merah tidak berguguran.

Media tanam cocopeat : tanah dengan perbandingan 1:2 terbukti menghasilkan jumlah daun tanaman yang lebih banyak. Diduga sumber hara di dalam media ini lebih disediakan oleh tanah karena cocopeat yang digunakan belum terurai sempurna sehingga penggunaan cocopeat yang lebih sedikit justru menghasilkan tanaman yang lebih tinggi dibandingkan penggunaan cocopeat yang lebih banyak. Sesuai dengan pendapat Ramadhan *et al.* (2018) yang menyatakan bahwa penggunaan cocopeat yang belum terdekomposisi secara sempurna mengandung rasio C/N yang tinggi. Tingginya rasio C/N tersebut menandakan konsentrasi unsur nitrogen di dalam media lebih sedikit, sehingga tanaman kekurangan unsur nitrogen untuk kebutuhan pertumbuhan tanamannya.

Sukarman *etal.*(2012) menyebutkan faktor penghambatan pertumbuhan tanaman pada media cocopeat yang belum terdekomposisi sempurna disebabkan oleh keberadaan senyawa tanin. Fahmi (2013) menambahkan media tanam cocopeat yang masih mengandung tanin dapat meracuni tanaman, sedangkan cocopeat yang siap pakai sebelumnya telah direndam dengan air tawar atau kapur untuk menghilangkan senyawa tanin. Dari hasil penelitian ini, maka aplikasi *compost tea* yang dikombinasikan dengan media tanam dapat menjadi salah satu alternatif pertanian organik modern yang memiliki tingkat kesuksesan budidaya tinggi. Pendapat ini didukung oleh hasil jumlah daun yang meningkat dalam penelitian ini akibat dari kombinasi *compost tea* aerasi dengan media tanam cocopeat: tanah (1:2).

KESIMPULAN

Dari hasil penelitian ini dapat diambil kesimpulan bahwa Semua perlakuan baik *compost tea*, media tanam, maupun interaksi diantara keduanya meningkatkan semua parameter yang diukur sebagai hasil dari pertumbuhan tanaman bayam merah yang lebih baik daripada tanaman kontrol. Kombinasi *Compost tea* dan komposisi media tanam cocopeat : tanah yang terbaik dalam meningkatkan pertumbuhan tanaman bayam merah (*Amaranthus tricolor L.*) ialah *Compost tea* aerasi pada media tanam cocopeat : tanah (1:2).

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EXTRACT OF BITTER MELON (*MOMORDICA CHARANTIA L.*) AS A CYTOTOXIC AND ANTI PROLIFERATION AGENT FOR CELLS WIDR (COLON CANCER)

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Abstract

Colon cancer is one of the types of cancer that gives a high mortality rate. Many people with colon cancer do not realize they have colon cancer because the initial spread does not show severe symptoms. Colon cancer occurs due to cell abnormalities caused by DNA mutations. To reduce the death rate caused by cancer, there have been many attempts to find effective treatments, both modern and traditional. Modern treatments such as surgery and chemotherapy still often have adverse effects on sufferers. Therefore new efforts are made to find alternative treatments, one of which is the traditional way of exploring natural ingredients and utilizing secondary metabolites produced by plants. Pare (*Momordica charantia L.*) is an anticancer candidate characterized by the presence of cytotoxic saponins momordicosides, flavonoids, and alkaloids as inhibitors of cell development processes. This study's objectives were (1) To determine the cytotoxic effect of bitter melon (*M. charantia L.*) extract on reducing the number of colon cancer cells (WiDr), (2) To determine the effect of the proliferation of bitter melon (*M. charantia L.*) extract on reducing the number of colon cancer cells (WiDr). The results obtained for the cytotoxic test, namely the IC₅₀ value of 111 µg / ml, were said to have quite toxic properties and were able to have anticancer activity. The proliferation test showed that EBP inhibited the proliferation rate at the 24-hour incubation period and had time to increase at a concentration of 13,875 µg / ml with values above 400 hours.

Keywords: Colon Cancer, Cytotoxic, *Momordica charantia L.*, Proliferation.

1 Introduction

Cancer, also known as a malignant neoplasm, is a disease characterized by cell cycle abnormalities that cause cells' ability to grow out of control [1]. Colon (colorectal)

cancer is one of the most common causes of death in the world, with America an estimated incidence of 75,610 cases in men and 64,640 cases in women with an overall average of about 80,000 deaths per year [2] while for Indonesia, colon cancer includes ten primary cancers are common [3].

Colon cancer, which grows on the surface of the colon (intestine) or rectum (anus), which is part of the large intestine in the digestive system, is also called the gastrointestinal tract, which functions as a producer of energy for the body and removes waste products that are not useful [4]. Today, medical practitioners generally have three ways of treating cancer, namely surgery, radiation, and chemotherapy [5].

Surgery is an invasive treatment procedure through incisions to open or reveal parts of the body that will help generally experience a high increase in cancer cells that have not metastasized (spread), the effects of surgery failure can cause cancer to spread to other body tissues and worsen the condition. Radiotherapy, which uses radioactivity to destroy tumor cells. The advantage is that it only causes minor damage to the surrounding normal tissue. The types of radiation rays commonly used are gamma rays (γ) and X-rays [6].

Chemotherapy is a treatment effort to kill cancer cells by giving synthetic chemotherapy drugs, unlike surgery or radiation locally, chemotherapy is spread throughout the body because it is a systemic therapy, which means the drugs given spread throughout the body. So that the resulting effect will make sufferers experience anemia, thrombocytopenia, leucopenia, nausea, vomiting, alopecia, stomatitis, allergies, pain and tissue necrosis [7].

Bitter melon has a bitter taste caused by the content of momordicosides of the triterpene glucoside group or kukurbitasin which are very patent antiproliferative and anti-differentiation properties. Efforts to develop alternative preparations in traditional medicine that can replace synthetic chemotherapy drugs and are relatively more effective in increasing body immunity. Traditional medicine that is often used comes from natural ingredients, namely plants, by knowing secondary metabolite compounds' content.

bitter melon contains saponins and is cytotoxic. Cytotoxics are substances or compounds that can damage cancer cells. Flavonoids inhibit a number of cell development processes in the body through inhibition of a number of enzymatic reactions as well as potential anti-cancer drugs. The United States NCI (National Cancer Institute) states that an extract or compound can be said to be potential as an anticancer agent if it has an IC value of $<50 \mu\text{g} / \text{ml}$ and if an extract or compound has an IC value of $> 140 \mu\text{g} / \text{ml}$ then the extract or compound is said to be not. It is toxic and has no anticancer activity [8]. Proliferation inhibition activity can occur due to alkaloid and flavonoid compounds in the bitter melon extract that can stimulate enzymes to inhibit the cell cycle, as an antiproliferation and angiogenesis of cancer cells [9].

The mechanism for inhibiting proliferation occurs probably because cells die. This cell death can go through the cell cycle mechanism to stop (arrest) by stopping the cell cycle, so the cells cannot reproduce themselves.

2 Method

2.1. Material

The material used in this research was bitter melon, 96% ethanol, cell culture for cytotoxic and proliferation test: culture media in the form of Roswell Park Memorial Institute (RPMI), phosphate buffer saline (PBS), solvent methanol, dimethyl sulfoxide (DMSO), propidium iodide, trypsin EDTA, microtetrazolium (MTT), sodium dodecyl sulfate (SDS) 10%, ethidium bromide-acridine orange.

2.2. Equipment

Include a set of extraction tools in the form of a cutting knife, plastic tub/trough, oven, mortar, Buchner, funnel and filter paper, rotatory evaporator. The cytotoxic and proliferation test kits for colon cancer cells are liquid nitrogen tank, water bath, laminar airflow, refrigerator, Eppendorf tube, centrifuge tube, centrifugation, micropipette 10, 20, 200, and 1000 μ L, small test tube, six and 96-well plate, conical tube, yellow tip and blue tip, Elisa reader, vortex, coverslip, hemocytometer, CO₂ incubator, the waste container for used media for phosphate buffer saline (PBS), tissue, aluminum foil, fluorescence microscope.

2.3. Research Implementation

This research consists of several stages, namely 1). Sample preparation ; 2). WiDr cell cytotoxic test (Microtetrazolium method); and 3). WiDr cell proliferation test (Doubling time Methode). This research stage is presented in figure 1.

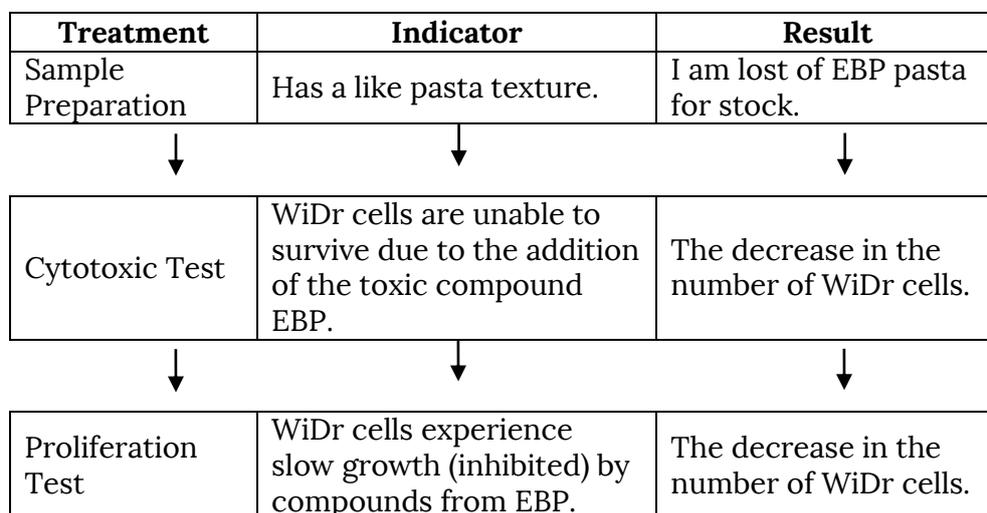


Figure 1. Research Implementation

3 Result and Discussion

The results obtained for cytotoxic were the highest average absorbance of living cells after being given EBP at a sample concentration of 50 μ g/ml with a value of 101,0737%. The lowest was at a concentration of 275 μ g ml, with a value of 0,572656%. With an increase in EBP concentration, it can have a cytotoxic effect on WiDr cells so that the number of WiDr cells so that the number of surviving cells decreases; however,

based on the data in Table 1, the average percentage of living cells gives varied results, even at the highest concentration of 300µg/ml EBP gives the value of % living cells of 2,791696 which is lower than the percentage of living cells at the concentration below.

It is assumed that too high a concentration is not too good and can result in cells having higher adaptability. To determine how toxic a substance or extract is, it is necessary to calculate the IC₅₀ value. IC₅₀ can be seen directly from the number 50 on the percentage results of the ability to live cells. The number 50% of living cells fall into the concentration range between 125µg/ml to 100µg/ml. The IC₅₀ value obtained was 111 µg/ml. These results are used for the proliferation test.

Table 1. Mean Percent Absorbance of Live Cells

Concentration (µg/mL)	Absorbance EBP			Mean % Live Cell	SD
	P1	P2	P3		
300	0,143	0,137	0,140	2,791696	0,003000
275	0,137	0,126	0,126	0,572656	0,006351
250	0,130	0,137	0,123	0,644238	0,007000
225	0,302	0,126	0,136	13,09950	0,098853
200	0,354	0,147	0,146	19,04080	0,119801
175	0,207	0,209	0,201	16,89334	0,004163
150	0,264	0,273	0,31	33,35719	0,024379
125	0,358	0,362	0,353	49,53472	0,004509
100	0,460	0,445	0,465	70,79456	0,010408
75	0,545	0,579	0,558	93,12813	0,017156
50	0,614	0,611	0,568	101,0737	0,025736
25	0,578	0,592	0,575	97,63780	0,009074

Based on the data above, EBP has an IC value of <150 µg / ml, and it can be said that EBP is categorized as quite toxic and has anticancer activity. This is evidenced by the research [10] that the IC₅₀ value <150 µg / ml is categorized as quite toxic and has a positive correlation as an anticancer agent. The United States NCI (National Cancer Institute) states that an extract or compound can be said to be potential as an anticancer agent if it has an IC value of <50 µg / ml and if an extract or compound has an IC value of > 140 µg / ml then the extract or compound is said to be not. It is toxic and has no anticancer activity [8].

The chemical content of unripe bitter melon fruit, which has medicinal properties, is saponins, flavonoids, alkaloids, polyphenols [11], and cucurbitacin glycosides, charantin, butyric acid, steroid compounds, monocyclic alcohol, and some triterpenoid compounds [12]. This is following the latest research conducted by [13], which states that the ethyl acetate fraction of 70% ethanol extract from bitter melon has high toxicity properties to HeLa cells with an incubation period carried out within 24 hours and 48 hours of the ethyl acetate fraction from ethanol extract 70% incubation 24 and 48 hours amounted to 34,9221 and 22,1871 µg/ml.

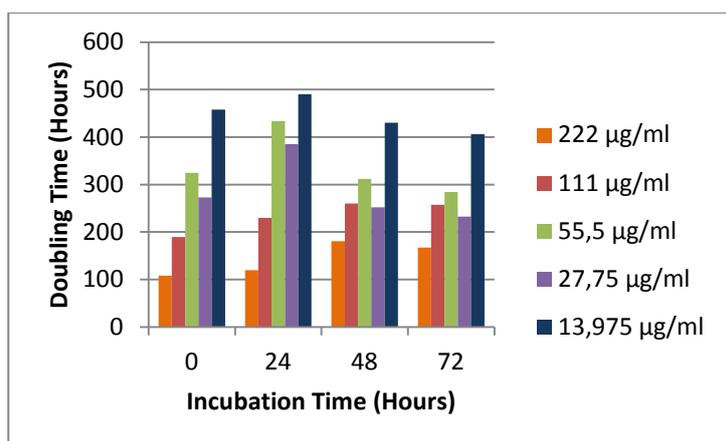


Figure 2. Diagram of the Doubling Time of WiDr Cell Proliferation

The results of the proliferation test using the Doubling Time method can be seen in Figure 2. It proved that the adequate concentration time to inhibit cell growth is in the 24-hour incubation period. This is following that at 24 hours, and there is a decrease in the number of living cells. The highest doubling time value, namely at a concentration of $1 / 8IC_{50}$ or $13,875 \mu\text{g/ml}$, had a length of time for cells to divide into two times the initial time at each incubation time of 400 hours. Meanwhile, the concentration of $2IC_{50}$ or $222 \mu\text{g/ml}$ has a shorter doubling time than other concentrations, which is at 100 hours. This can be caused by cell death. This cell death can go through the cell cycle mechanism to stop (arrest) by stopping the cell cycle, so the cell cannot reproduce itself.

Proliferation inhibition activity can occur due to the presence of alkaloid and flavonoid class compounds contained in bitter melon fruit extract, as stated by [14] that the positive bitter melon contains secondary metabolite compounds, namely flavonoids. Flavonoids can stimulate enzymes to inhibit the cell cycle as an antiproliferation and angiogenesis of cancer cells [7]. The mechanism for inhibiting proliferation occurs probably because cells die. This cell death can go through the cell cycle mechanism to stop (arrest) by stopping the cell cycle, so the cell cannot reproduce itself. According to [15], proliferation inhibition can also occur through the formation of DNA fragmentation, decreased Bcl mRNA expression, and increased Bax mRNA expression.

4 Conclusion

Conclusions that can be drawn from the research conducted bitter melon fruit are:

1. the cytotoxic effect of bitter melon extract can reduce the number of colon cancer cells (WiDr). Bitter melon are toxic to colon cancer cells WiDr, for the cytotoxic test, namely the IC_{50} value of $111 \mu\text{g/ml}$, was said to have quite toxic properties and were able to have anticancer activity.
2. The proliferative effect of bitter melon extract can inhibit proliferative activity and reduce the number of colon cancer cells (WiDr). The bitter melon fruit extract can also reduce the growth of colon cancer cells WiDr by reducing the rate of cell proliferation. The proliferation test showed that EBP inhibited the proliferation rate at the 24-hour incubation period and had time to increase at a concentration of $13,875 \mu\text{g/ml}$ with values above 400 hours.

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ANALYSIS OF PROTEIN PROFIL OF CASSAVA (*MANIHOT ESCULENTA CRANTZ.*) MUTANT PLANLETS RESISTANT TO FUSARIUM WILT

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ABSTRACT

Cassava (*Manihot esculenta* Crantz.) Is generally grown by Indonesian farmers because it is an important food source of carbohydrates after rice and corn, but there are still many production constraints in cassava cultivation, including Fusarium wilt. This disease is caused by the fungus *Fusarium oxysporum* (Fo). Fusarium wilt disease is characterized by the plant wilting rapidly, the roots rot, the plant droops as if it is about to collapse, and white fungal colonies are visible at the base of the tuber. Disease control that does not cause negative impacts can be carried out through in vitro selection in media with the addition of fusaric acid. The purpose of this study was to determine the concentration of fusaric acid that comparing the protein profile between cassava resistant to Fo by control. This study used a completely randomized design (CRD) with one factor, namely fusaric acid which was divided into 5 levels of concentration, namely 0 ppm, 60 ppm, 80 ppm, 100 ppm, and 120 ppm. Each of these concentrations was repeated 5 times, and each replication consisted of 2 cassava plantlets (*Manihot esculenta* Crantz.) In each culture bottle. The research data is in the form of qualitative and quantitative data. Qualitative data is presented in descriptive form and supported by photos, while quantitative data from each parameter is analyzed using Analysis of Variance or Anova which is carried out at the 5% real level and further tests with the LSD (Least Significant Difference) test at the real level 5 %. The outcome of the study, in the form of a Cassava mutant with a new protein bands (molecular weight 98 kDa), missing protein bands (65 kDa molecular weight), and proteins whose bands are consistent and thick (25 kDa).

Key words: Fusaric acid, Cassava (*Manihot esculenta* Crantz.), *Fusarium oxysporum*, In Vitro, Protein profile

INTRODUCTION

Cassava (*Manihot esculenta* Crantz.), is the third most important crop in the world and a staple food source and income throughout the tropics (Eleazu *et al.*, 2014). Cassava cultivation can be a livelihood for more than 500 million farmers (Amponsah *et al.*, 2014). Cassava is an important food commodity in Indonesia, and in the future this commodity will have a more strategic role in the lives of the people and the country's economy. Based on the area of harvest of food commodities, cassava ranks third after rice and corn, which are the three main sources of carbohydrates in the community (Fauzi *et al.*, 2015). One of the problems encountered in cultivating Cassava is Fusarium wilt caused by the fungus *F.oxysporum* (Fo) and is medium-transmitted. Arinze (2005); Okigbo (2009) reported that 50% of Cassava tubers produced and harvested in Nigeria were lost due to disease. The main causes of decay of Cassava include: *Aspergillus flavus*, *Aspergillus niger*, *Botryodiplodia theobromae*, *Collectotrichum* spp, *Geotrichum candidum*, *Penicillium chrysogenum*, *Pennicillium digatum*, *Fusarium oxysporum* (Ogunleye *et al.*, 2014; Okigbo *et al.*, 2015; Gwa *et al.*, 2015). This organism reduces the quantity and quality of the plant tubers (Amusa *et al.*, 2003). The Central Statistics Agency noted that the Cassava land center in Indonesia was controlled by Lampung province with a harvest area of 324,100 ha in 2012. In 2013, cassava production in Lampung Province reached 8.33 million tons and in 2015 it was 7.39 million tons. This situation makes Lampung a supplier of one-third of national Cassava production from national production of 23.92 million tons, however there are still many production constraints in Cassava cultivation, including Fusarium wilt disease. This disease is caused by the fungus *Fusarium oxysporum* (Fo) which until now still cannot be effectively treated. One alternative method of controlling disease that is efficient, effective and safe to the environment, among others, uses resistant varieties. The use of high yielding varieties that are resistant to high yielding fo is one important alternative disease control and does not cause negative impacts. Development of Fo resistant cassava varieties can be carried out by *in vitro* selection methods, namely culturing explants in the form of tissue or organs in a medium containing selective fusaric acid concentration (Nurcahyani *et al.*, 2016a; Nurcahyani *et al.*, 2016b; Nurcahyani *et al.*, 2014; Nurcahyani *et al.*, 2017; Nurcahyani *et al.*, 2019; Nurcahyani *et al.*, 2020). Research on Cassava Induced Resistance with fusaric acid (FA) has been carried out previously, and found indications of tolerant FA concentration for selection of *in vitro* resistant plantlets. The results of this research that have been carried out are also in line with previous research on the *Vanilla planifolia* Andrews plantlet that there was a new protein band (molecular weight 18 kDa) which was predicted to be a protein mutant resulting from fusaric acid induction at concentrations of 90, 100, and 110 ppm (Nurcahyani *et al.*, 2012).

Material and Methods

The tools used in this research are tweezers, scalpel, micropipette, test tube, test tube rack, microwave, hot plate, ohaus analytical scales, waterbath, petridish, tissue, shaker, label paper, camera. , electrophoresis apparatus, and spectrophotometer. The materials used in this study were cassava plantlets (*Manihot esculenta* Crantz.) Which

had been given pure fusaric acid, 70% alcohol and distilled water, solution A, solution B, solution D, and protein molecular weight marker (Page-Ruler Low Range Unstained Protein Ladder) acrylamide / bisacrylamide solution, Tris-HCl buffer, Sodium Dodecyl Sulfate (SDS), electrophoretic buffer solution, Reducing Sample Buffer (RSB) (Maniatis *et al.*, 1982). The methods used in this study include:

Protein profile analysis of cassava (*Manihot esculenta* Crantz.) Plantlet using SDS-PAGE method Protein Concentration Measurement. After the crude protein is obtained, measurement of the protein concentration in each sample is carried out. The concentration of protein samples was determined using the Bio-rad method (Bio-rad Assay). Calculation of protein concentration profile is using Bovin Serum Albumin (BSA) which is used as a standard of protein concentration. The blanks used were 200 μ L bio-rad dye and 800 μ Lakuades. Determination of protein concentration was carried out by taking 2 μ L from the protein sample using a micropipette plus 200 μ L Bio-rad dye and 798 μ L of distilled water, then suspended it so that it was mixed and then read using a spectrophotometer at a wavelength of 595 nm. The protein concentration can be determined through the equation of the standard BSA protein standard curve function.

Determination of Protein Molecular Weight. Determination of protein molecular weight using the SDS-PAGE (Sodium Dodecyl Sulphate-Polyacrylamide Gel Electrophoresis) method according to Maniatis *et al.*, (1982). The sequence of this model, namely resolving gel 12% (distilled water 3.3 mL, polyacrylamide 4 mL, 1.5 M Tris pH 8.8 2.5 mL, 10% SDS 100 μ L, 10% APS 90 μ L) was inserted into the plate pair. glass as a gel mold and wait for the gel to polarize. Stacking gel 6% (distilled water 2.6 mL, polyacrylamide 1 mL, 0.5 M Tris pH 6.8 1.15 mL, 10% SDS 50 μ L, TEMED 10 μ L, 10% APS 90 μ L) is put on top of the resolving gel and fitted with a comb that is used to make a well to insert a sample of protein. After polarized gel stacking, the gel is removed from the mold and the plates are assembled with the electrophoresis apparatus. Running buffer 0.1% (1 L distilled water, 15 g Tris Base, 72 g glycine, 5 g SDS) is poured into the tub and the comb is removed. Then 10 μ L of protein samples were mixed with 2 μ L of buffer samples. All solutions were heated in boiling water for 2 minutes and immediately cooled in shards of ice. The protein sample solution and protein marker were added to the gel well (12% acrylamide gel). Electrophoresis at a voltage of 100 volts is carried out for 1.5 - 2.5 hours. The protein bands with the larger molecular weight will form closer to the initial site of the separation. The staining of the protein bands was done by immersing the gel from the electrophoresis (a series of plates removed) in a 0.10% solution of Coomassie Brilliant Blue and was done using a shaker. Then after staining, destaining is carried out to remove the color by immersing the gel in a destaining solution (500 mL of distilled water, 40 mL of methanol, 10 mL of glacial acetic acid) until the gel becomes clear with separate bands from each other. The gel was then stored in 10% glacial acid and dried with a plate kit. The protein bands formed in the gel after electrophoresis are then determined by their molecular weight.

Result and Discussion

In this study, using cassava plantlet (*Manihot esculenta* Crantz.) *In vitro* and treated with various levels of fusaric acid. The fusaric acid used in this study contained five different concentration levels, namely 0 ppm (control), 60 ppm, 80 ppm, 100 ppm, and 120 ppm. The results of the selection of cassava plantlets that have been induced using fusaric acid with various different concentration levels are presented in Figure 1.

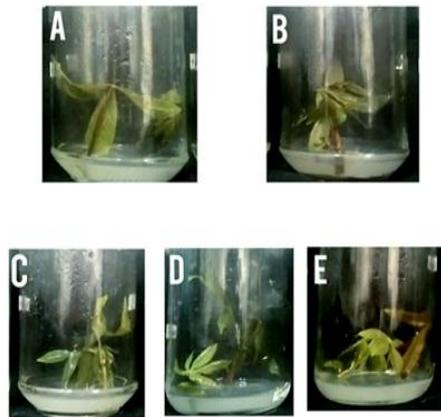


Figure 1. Cassava plantlets with various concentrations of fusaric acid (A) 0 ppm “Control”, (B) 60 ppm, (C) 80 ppm, (D) 100 ppm, (E) 120 ppm

From the picture above, it shows that the cassava plantlets were each treated with a chemical compound in the form of fusaric acid. The function of giving treatment with fusaric acid is to find out plantlets that are resistant to *Fusarium oxysporum*. The treatment indicated that the resistance of cassava plantlets was getting better with the increase in the concentration of fusaric acid used, except at a concentration of 120 ppm. The higher the fusaric acid concentration, the better the cassava plantlet compared to the control one. This shows that the cassava plantlets given fusaric acid treatment with various concentrations were better than the cassava plantlets without treatment, namely control. Seen in Figure A. (plantlets without fusaric acid treatment) there are clear signs that the plantlets are wilted, which indicates that the plantlets are not resistant. Unlike the case with cassava plantlets which were given fusaric acid treatment with various concentrations, as in Figure 3 parts (B, C, and D) it is clear that these plantlets have better resistance to control where the increasing concentration of fusaric acid, the the more increasing the resistance. This is in line with previous research conducted by Nurcahyani *et al.* (2019) showing that the best concentration of fusaric acid in reducing fusarium wilt disease resistance in cassava plantlets, namely at the highest concentration of 80 ppm, resulted in 70% green cassava plantlets and green color. chocolate as much as 30% with a percentage of the number of lives 100%. In this study, there was a slight difference from previous studies where the fusaric acid concentration of 120 ppm cassava plantlets had mortality as much as 50% of the total number of plantlets. It can be seen in Figure E. (120 ppm fusaric acid treatment) that the cassava plantlet looks brownish green to brown which indicates that the plantlet has died.

From the plantlets, then from each treatment the concentration of fusaric acid was taken as a sample, then analyzed the protein profile.

Protein profile analysis of cassava (*Manihot esculenta* Crantz.) Plantlet using SDS-PAGE method

Proteins are the end product of gene expression in prokaryotic and eukaryotic organisms, and proteins are considered molecules that offer many roles and a very diverse range of functions within cells. Because of this, for a long time, protein isolation and characterization has been one of the most interesting subjects for researchers from various areas of interest (Batista *et al.*, 2015). The protein profile analysis of cassava (*Manihot esculenta* Crantz.) Was carried out using sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE). This method is a method that is widely used. In this study, 2 types of gel were used, namely the stacking gel and the separating gel. The gel contains acrylamide, sodium dodecyl sulfate (SDS), ammonium persulfate (APS) and TEMED. The results of the protein profile analysis are attached in Figure 2 below.

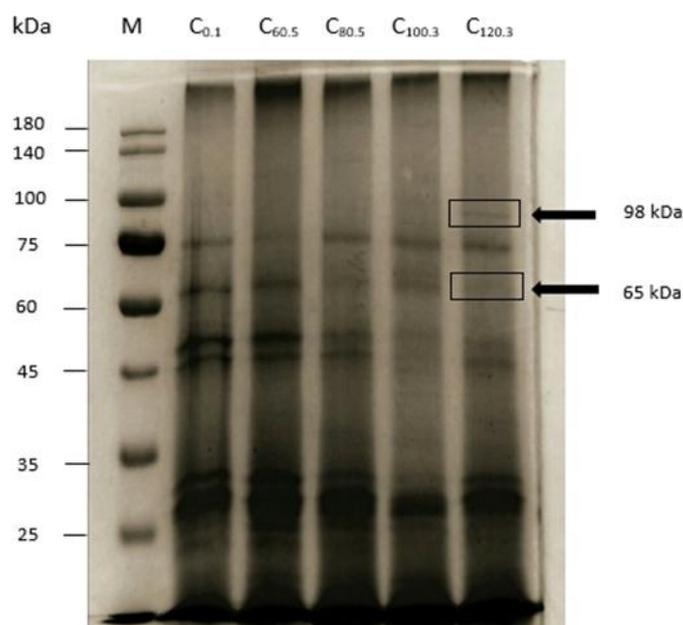


Figure 2. Protein profile of cassava plantlet leaves after induction fusaric acid using the SDS-PAGE method

Based on the results of SDS-PAGE, the protein profile of cassava (*Manihot esculenta* Crantz.), There were findings in the form of a new band, namely a band at a molecular weight of 98 kDa (fusaric acid concentration treatment 120 ppm), and there was also a missing protein band at a molecular weight of 65 kDa. (Fusaric acid concentration treatment 120 ppm). According to Gunanti *et al.* (2010), the protein band thickness of the SDS-PAGE results illustrates the high and low concentration of a protein contained in the test sample. In this study, the thickest and clearest and also consistent protein bands appeared in almost every individual from each treatment

group, namely bands with a molecular weight of 25 kDa. The presence and thickness of the protein bands that are formed depend on the type, number, and sequence of amino acids. This is what causes the differences in each protein that is formed. Likewise, the new band that is formed is the result of a reaction or biochemical process that is formed between plants with the application of both liquid extract and inorganic fertilizers, where in this study the formation of new bands is the result of reactions or biochemical processes. which was formed between cassava and fusaric acid (AF) with different treatments in it.

The composition of the gel used influenced the results of running cassava samples (*Manihot esculenta* Crantz.). The gel acts as a pore or filter that will filter these proteins based on the order of their molecules. In this case, the protein with a small molecular weight will first drop quickly to the bottom of the gel, and vice versa, the protein with a large molecular weight will be stuck in the top gel. If the gel composition used is not suitable, for example, the gel composition is too small, the pores in the gel become loose so that the protein with small molecular weight will continue to decrease, whereas if the gel composition is too large, the pores of the gel become tight so that the protein with large molecular weight will get stuck. The sample buffer solution is used as a stacking dye to function as a marker for the protein stuck in the gel pore as a band. Prior to heating, the protein is given a buffer sample solution with the aim of releasing the complex protein bonds into a simple bond which will make it easier to carry out the running electrophoresis process.

The addition of the sample buffer solution was treated, after which the protein sample is heated to optimize the process of protein denaturation. Protein separation was carried out using the SDS-PAGE (*Sodium Dodecyl Sulfate - Poly Acrylamide Gel Electrophoresis*) method (Laemmli, 1970). Can be used to view protein profiles and determine BM or protein molecules. Proteins can be separated from other types of protein or from other molecules based on their size, solubility, charge, and bond affinity. Protein separation is a step that must be taken to study the properties and functions of proteins. Various types of protein in a sample will be separated on a polyacrylamide gel which is very dependent on mobility, polyacrylamide has the advantage of not reacting and does not form a matrix with the sample (La'lang *et al.*, 2018). The thickness and thinness of protein bands seen is an illustration of the amount of protein content in the molecular weight of a protein.

In this study, there were two conclusions, namely, the emergence of a new protein band, then the loss of one of the protein bands, each of which was found in the 120 ppm fusaric acid treatment. In line with the research on cassava plantlet DNA pattern analysis conducted by Nurcahyani *et al.* (2019) stated that the difference in the banding pattern was due to the amplification process of the DNA strands at a certain position. Based on the 2 banding patterns formed, 1 new DNA band (specific) was obtained, namely 550 bp (primer OPA_1). These specific DNA bands can be used as characters to classify and separate cassava plantlets that are not affected (control) and AF-induced (concentrations of 20, 40, 60, 80 ppm). The results of PCR DNA amplification showed that moderate and resistant cassava plantlets at AF 40, 60, and 80 ppm formed new

DNA bands, which meant that there had been genetic variations and gene mutations. From this incident, these specific bands indicated the identification of new cultivars of cassava plantlet resistant to *Fusarium oxysporum* and it can be said that the emergence of a new DNA band pattern indicates that cassava plantlets that have been treated with fusaric acid with various concentrations are plantlets that are resistant to fusarium wilt disease caused by *Fusarium oxysporum*.

Conclusion

There are new protein bands (molecular weight 98 kDa) at 120 ppm fusaric acid concentration, missing protein bands (65 kDa molecular weight) at 120 ppm fusaric acid concentrations, and proteins whose bands are consistent and thick (25 kDa) at all concentrations.

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THE EFFECT OF BLACK PEPPER ON INTRATESTICULAR TESTOSTERONE LEVELS AND SPERMATOGENESIS OF MICE INDUCED WITH PROGESTIN HORMONE

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ABSTRACT

The progestin hormone is a hormone that used as male contraception. Giving progestin to normal men will suppress testicular function effectively, reduce the number of spermatozoa, suppress libido, and reduce testosterone levels so that it can decrease fertility. Black pepper (*Piper nigrum* L.) is a traditional plant that can increase fertility. Black pepper contains piperine, essential oils, alkaloids, amide acids, flavonoids, magnesium, and zinc which have been shown to increase fertility. This study conducted to examine the effectiveness of black pepper (*Piper nigrum* L.) extract on intratesticular testosterone levels and spermatogenesis in mice (*Mus musculus* L.) induced by progestin. Twenty male mice were divided into four treatment groups. Group P0 as a control (given H₂O), P1 (induced by 1.25 mg progestin hormone), P2 (induced by 1.25 mg progestin hormone and 3.33 mg / Kg BW black pepper ethanol extract), and P3 (induced by 1.25 mg progestin hormone and 3.33 mg /Kg BW water extract of black pepper). The progestin hormone was given twice (week 1 and week 2). Black pepper extract was given daily for 35 days. The results showed that giving black pepper extract significantly increased intratesticular testosterone levels of progestin-induced. As the conclusion, blackpepper extract can increase intratesticular testosterone levels and spermatogenesis in mice that are induced by the progestin hormone.

Keyword: black pepper, intratesticular testosterone levels, progestin hormone.

INTRODUCTION

The prevalence of infertility varies widely especially in developing countries because of limited resources for investigation and available treatment. In Indonesia, there are 12% or about 3 millions couple are infertile. It is known that 30% of all cases of infertile couples are caused by the male (Sutyarso & Busman, 2003). In some case, male infertility is caused by pathophysiological factors and idiopathic infertility or un-

explained infertility. Intensive diagnosis and treatment have been carried out, but there are still unknown and need to be explored further.

Several ways can be done to increase fertility in men. One of them is the traditional way, namely using black pepper extract. Black pepper (*Piper nigrum* L.) is a traditional plant that can increase fertility. Study of the chemical content of black pepper indicates that this plant contains active ingredients such as piperine, phenolic amides, phenolic acids, and flavonoids which are antioxidants very strong (Meghwal and Goswami, 2012). There are reports that piperine can increase plasma testosterone levels (Vijayakumar and Nalini, 2006).

There are several possible role of piperine in increasing testosterone levels in mice. Piperine the active constituent of *Piper nigrum* is known to have an inhibitory effect on testosterone 5 α -reductase. The inhibition of this enzyme causes testosterone levels remain high (Hirata *et al*, 2007). Research conducted by Sutyarso, *et al* (2016) shows that black pepper extract has a positive effect on testosterone levels and increases fertility in male mice. The next possibility that makes black pepper extract affect androgens secretion in male subject is minerals such as magnesium (Mg) and zinc (Zn) (Sutyarso *et al*, 2016). A supplement containing of Mg-Zn significantly increase free testosterone levels in strength-trained, competitive athletes (Brilla LR., 2000).

In this study, progestine hormone was used to induced male mice to become infertile. Progestine hormone is one of the hormones used as male hormonal contraceptives is the progestin hormone. Giving progestin to normal men will suppress testicular function effectively, reduce the number of spermatozoa, suppress libido, and reduce testosterone levels so that it can decrease fertility (Yurnadi *et al*, 2008). This study will examine the effect of black pepper (*Piper nigrum* L.) extract on intratesticular testosterone levels in mice (*Mus musculus* L.) induced by progestin.

MATERIAL AND METHODE

Plant extract

Black pepper was obtained from pepper fruit farmers in Lampung province and determined by Botanical Laboratory, Faculty of Mathematics and Natural Science Lampung University . The black pepper that has been selected was then dried in the oven until completely dry, then mashed. After that, ground black pepper was extracted by maceration method using ethanol and water (Kanedi *et al*, 2018).

Each 50g of black pepper powder were macerated with 500mL of 96% ethanol solvent for 3 \times 24h at room temperature. The macerate thus obtained was filtered with filter paper and the filtrate was evaporated using water bath until yellowish brown paste was obtained. And to make black pepper water extract, 50 grams of black pepper powder is put in 500 ml of distilled water that has been heated to a boil. then the mixture is stirred for 15 minutes. Then it is filtered. The filtrate is evaporated in an oven at 70°C until the extract is in the form of a paste. This paste is named as water extract (Ekaputri *et al*, 2014).

Animals and Treatment

Twenty male mice aged 2-3 months with a weight of 30g were obtained from the Center for Veterinary Investigation and Testing (BPPV) Regional III Bandar Lampung which were then divided into 4 treatment groups. Group P0 as a control (given H₂O), P1 (induced by 1.25 mg progestin hormone), P2 (induced by 1.25mg progestin hormone and 3.33mg / Kg BW black pepper ethanol extract), and P3 (induced by 1.25mg progestin hormone and 3.33mg /Kg BW water extract of black pepper). All treatment administered orally using stomach sonde once daily for 35 days. On day 36 all mice were sacrificed. Epididymal cauda was taken to check quantity and quality of spermatozoa and the testis organ is taken for measurement of intra-testicular testosterone levels using Enzyme-linked immunosorbent assay (ELISA).

All of research procedures was done with the approval and supervision of Health Research Ethi-cal Comission Faculty of Medicine University of Lampung No. 1746/ UN26.18/PP.05.02.00/2020.

Hormon assay

Twenty µL testicular homogenate samples were incubated with biotinylated monoclonal testo-sterone-specific antibody. The bind-ing area on the labeled antibody is occupied by the sample analyte (depending on the concentration). After the addition of streptavidin-coated microparticles and a testo-sterone derivative labeled with the ruthenium complex in the second step, the complex becomes bound to the solid phase through the interaction of biotin and streptavidin. The reaction mixture is aspirated into a small hole in the analyzer where the microparticles are magnetically captured on the electrode surface. Unbound substances are removed with Procell. Application of voltage to the electrodes induces chemilum-inescent emission as measured by a photomultiplier. The results are determined through a calibration curve generated from 2 calibration points and a standard curve presented via barcode reagent. The Elecsys 2010 analyzer calculates the analyte concentration of each sample auto-matically (Khatimah, 2015).

Statistical analysis

Data from the observation of testosterone levels in the form of ng/ ml. The data were analyzed using SPSS with the One-way ANOVA test. If there is significant diversity, the data will be tested further using the Least Significant Difference (LSD) test at the 5% real level.

RESULT AND DISCUSSION

Table 1. showed that percentage of intratesticular testoterone hormone in treatment 1 (P1) decreased compared to control (P0) while those given black pepper extract (P2 and P3) experienced an increase compared to treatment group 1 (P1). Intratesticular testo-sterone levels after ANOVA

analysis with a significance level of 5% showed significant results. The results of the LSD test on intratesticular testosterone levels showed a significant difference

between P0 and groups P1, P2, and P3, between P1 and P2, and between P2 and P3. There was no significant difference between the P1 and P3 groups.

Table 1. Effect of Black pepper extract on intratesticular testosterone and spermatogenesis of mice

Parameters	Treatment			
	P0	P1	P2	P3
Intratesticular testosterone levels (ng/ml)	87,97± 35,25	15,39±9,29	47,65 ± 19,82	27,03 ± 20,07
Sperm concentration (jt/ml)	35,60 ± 10,26	14,24 ±8,44	33,20 ± 12,72	22,56 ± 10,90
Sperm motility (%)	65,74 ± 19,53	25,28±24,34	43,44 ± 13,22	26,16 ± 16,09
Sperm viability (%)	73,12 ± 10,57	19,41±14,89	77,09 ± 11,01	64,09 ± 9,24
Normal morphology (%)	70,46 ± 8,88	38,46 ± 9,18	67,32 ± 5,70	66,53 ± 7,07

Note: P0: control, P1: induced progestin, P2: induced progestin+ etanol extract of black pepper, P3: induced progestin+water extract of black pepper.

Based on the results of the study, there was a decrease in intratesticular testosterone levels due to the provision of progestin hormone (P1) compared to the control group (P0). Progestin hormone is one of the most effective contraceptives in preventing pregnancy in the long term (Wahyuni, 2017). The progesterone hormone provides feedback to the pituitary gland via the hypothalamus. The production of testosterone in men is controlled by hormones by the hypothalamus-pituitary-gonad (HPG) axis. Gonadotropin-releasing hormone (GnRH) is secreted from the hypothalamus so that it stimulates the pituitary gland to release luteinizing hormone (LH) which acts on Leydig's testicular cells to produce testosterone (Walker and Cheng, 2005). The progesterone hormone can inhibit the secretion of Luteinizing Hormone (LH) and Follicle Stimulating Hormone (FSH). The inhibition of LH secretion will cause inhibition of the secretion of testosterone which functions in the spermatogenesis process so that it can reduce the number of spermatozoa. The number of spermatozoa produced is highly dependent on the spermatogenesis process that occurs in the seminiferous tubules. If during the spermatogenesis process there is a disturbance, the development of spermatogonia cells will affect the number of spermatozoa formed (Nurhadijah et al., 2018).

The disruption of the spermato-genesis process will also reduce the motility of the spermatozoa because the activity of the ATP-ase enzyme in the spermatozoa cell membrane in the middle of the tail is disturbed. The ATP-ase enzyme maintains internal homeostasis for sodium and potassium ions. If the activity of the ATP-ase enzyme is disrupted, the homeostasis of sodium and potassium ions will be disturbed so that the intracellular Na concentration increases, the Na + gradient across the cell

membrane will decrease so that the excretion of Ca will also decrease. If the Ca²⁺ ion is reduced, the membrane will lose its ability to transport materials- dissolved material into the cytoplasm. Disturbing the permeability of the sperm membrane will disrupt the transport of nutrients needed by spermatozoa for their movement (Julia et al, 2019).

The hormone testosterone is also very important in maintaining the ability of spermatozoa to survive while in the epididymis. The process of maturation of spermatozoa in the epididymis will be disrupted if there is a decrease in the hormone testosterone, where the hormone testosterone is needed by the epididymis for electrolyte transport for spermatozoa needs (Mughniati et al, 2018).

In addition, the decrease in testosterone also causes inhibition of the secretion of substances that support the process of spermatozoa in the epididymis, such as ions (Ca, Na, Cl), substrates (protein, sialic acid, glycogen, lactic acid, phospholipids), and enzymes (LDH, acid phosphatase and alkaline phosphatase). If these supporting substances are not available in sufficient quantities, it will cause the spermatozoa to not obtain energy, enzymes and nutrients so that the spermatozoa die (Julia et al., 2019). The decrease in testosterone level also has affect the sperm maturation process in the epididymis. As a result, there is an increase in abnormal morphology in spermatozoa (As et al., 2019). So that if injected into men, the hormone progesterone can reduce levels of Androgen Binding Protein and testosterone which results in decreased fertility in men (Manuaba, 1998).

The results also showed that giving ethanol extract of black pepper (P2) and water extract of black pepper (P3) with a dose of 3.33 mg/ Kg BW each could increase the level of intratesticular testosterone, concentration, and quality of spermatozoa which decreased due to the provision of the progestin hormone. However, in giving water extract of black pepper there was no significant difference with the treatment group which was only given the progestin hormone. Ethanol extract of black pepper was more effective in increasing intratesticular testosterone levels compared to water extract of black pepper. The black pepper extract which is macerated using ethanol has a stronger effect because it has more active ingredients. The ethanol compound used in the maceration process can attract many active compounds found in black pepper so that the effect is strong (Tahir and Moeen, 2011). Research conducted by Sutyarso, et al shows that giving ethanol extract of black pepper at a dose of 3.33 mg/ Kg BW can increase serum testosterone levels in male mice (Sutyarso et al, 2016) Another research by Ekaputri, et al shows that giving black pepper extract at a dose of 3.33 mg/Kg BW can increase the hormone FSH and testosterone (Ekaputri et al, 2018).

Black pepper (*Piper nigrum* L.) is used to stimulate the production of androgen and estrogen hormones which are the main provisions for generating sexual arousal in men and women (Siswoyo, 2004). Extract of black pepper can increase the weight of the reproductive organs and increase the hormone testosterone and enzymes in the reproductive organs (Mbongue et al, 2005).

Black pepper (*Piper nigrum* L.) has the main content, namely piperine. Piperine is known to have an inhibitory effect on testosterone 5 α -reductase. Inhibition of this enzyme causes testosterone levels to remain high (Hirata et al, 2007). Piperine has been

reported to increase gonadotropin levels in serum by inhibiting negative feedback to the anterior pituitary in male rats. So that gonadotrophin will stimulate the pituitary gland to release luteinizing hormone (LH) which acts on the Leydig testicular cells to produce testosterone (Walker and Cheng, 2005). Piperine is known to increase the hormone testosterone by minimizing conversion of testosterone to estrogen (Manjunatha H., 2007). In addition, black pepper extract also contains minerals such as Magnesium (Mg) and Zinc (Zn) which can increase free testosterone levels and increase androgen secretion in men (Brilla and Conte, 2000).

CONCLUSION

In conclusion, extract of black pepper (*Piper nigrum* L.) increased intratesticular testosterone levels, quantity, and quality of spermatozoa in male mice (*Mus musculus* L.) which is induced by progestin hormone. Giving ethanol extract of black pepper was more effective than water extract of black pepper in increased intratesticular testosterone levels.

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THE LOCATING CHROMATIC NUMBER FOR SPLIT GRAPH OF CYCLE

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ABSTRACT

The minimum number of colors in a locating coloring of G is called the locating chromatic number of graph G , denoted by $\chi_L(G)$. Split graph of cycle with a set of vertices $\{v_1, v_2, v_3, \dots, v_n\}$ is graph obtained by adding on vertex v_i as many new k vertices $v^1, v^2, v^3, \dots, v^k$, so that each vertices $v^1, v^2, v^3, \dots, v^k$ neighbouring with each vertex that is neighbouring to vertex v_i in the cycle graph. Split graph of cycle, denoted by $spl(C_n)$ In this paper will be discussed about the locating chromatic number for split graph of cycle.

Keyword: color code, locating chromatic number, split graph of cycle.

1. Introduction

The locating chromatic number one of material in the graph theory examined by Chartrand *et al* [7]. The locating chromatic number determine by minimizing the number of colors used in the locating coloring location with different color codes at each vertex in the graph.

Let c be a proper coloring of a connected graph G with $c(u) \neq c(v)$ for adjacent vertices u and v in G . Let c_i is a set of vertices receiving color i , for $i \in [1, k]$ then $\pi = \{C_1, C_2, \dots, C_k\}$ be a partition of $V(G)$. The color code $C_\pi(v)$ of a vertex v in G is the ordered k -tuple $(d(v, C_1), d(v, C_2), \dots, d(v, C_k))$ with $d(v, C_i) = \min\{d(v, x) | x \in C_i\}$ for $i \in [1, k]$. If all distinct vertices of G have distinct color codes, then c is called a locating coloring of G . The minimum number of colors in a locating coloring of G is called the locating chromatic number of graph G , denoted by $\chi_L(G)$.

Chartrand *et al* [7] determined the locating chromatic number for classes of graph, namely complete graph, $\chi_L(K_n) = n$; the cycle graph obtained $\chi_L(C_n) = 3$ for odd n odd and 4 for even n . Chartrand *et al* [6] characterized all graph of order n with the locating number $n - 1$. They also gave some conditions of graph G in which $n - 2$ is an upper bound of its locating chromatic number. Asmiati [1] determined the locating chromatic number of amalgamation of stars, Asmiati *et al* [2] determined the locating

chromatic number of non-homogeneous amalgamations of stars and also

Asmiati [3] determined locating-chromatic number for non-homogeneous caterpillars and firecracker graphs. Welyyanti *et al* [4] found on locating chromatic number for graph with dominant vertices. Sofyan *et al* [5] studied locating chromatic number of homogeneous lobster. Purwasih and Baskoro [8]



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Published under licence by IOP Publishing Ltd 1 studied the locating chromatic number of certain halin graph. Recently, Ghanem *et al* [9] studied and found locating chromatic number of power of paths and cycles.

The following theorem is a basic theorem proved by Chartrand *et al* [7]. The neighbourhood of vertex u in connected graph G , denoted by $N(u)$ is the set of vertices adjacent to u .

Theorem 1.1(see[7]). *Let c be a locating coloring in a connected graph G . If u and v are distinct vertices of G such that $d(u, w) = d(v, w)$ for all $w \in V(G) - \{u, v\}$ then $c(u) \neq c(v)$. In particular, if u and v are non-adjacent vertices of G such that $N(u) = N(v)$, then $c(u) \neq c(v)$.*

The split graph is obtained by adding on each vertex v on G one new vertex v' , so that v' neighbouring with each vertex that is neighbouring with v in G , denoted by $spl(G)$. Split graph of cycle with a set of vertex $\{v_1, v_2, v_3, \dots, v_n\}$ is graph obtained by adding on vertex v_i as many new k vertex $v^1, v^2, v^3, \dots, v^k$, so that each vertices $v^1, v^2, v^3, \dots, v^k$ neighbouring with each vertex that is neighbouring to vertex v_i in the cycle graph. Split graph of cycle, denoted by $spl(C_n)$. Next theorem about the locating chromatic number for a cycle graph (C_n).

Theorem 1.2(see [7]). *For $n \geq 3$, the locating chromatic number of a cycle graph (C_n) is 3 for odd n and 4 for even n .*

As long as the research, there is no theorem can determine the locating chromatic number for any graph. Research continues to get the locating chromatic numbers for other graph. Therefore, this paper will discuss about the locating chromatic number for split graph of cycle.

2. Results and discussion

In this section, we will discuss the locating chromatic number for ($spl(C_n)$).

Theorem 2.1. *Let $spl(C_n)$ be a split graph of cycle for $n \geq 3$. Then the locating chromatic number of*

$spl(C_n)$ is:

$\chi(spl(C)) = 4$, for odd n L $n \{5$, for even n *Proof:* Let ($spl(C_n)$), $n \geq 3$, be the split graph of cycle with the vertex set $V(spl(C_n)) = \{v_i, v'_i; 1 \leq i \leq n\}$ and the edge set $E(spl(C_n)) = \{v_i v_{i+1}; i$

$\in [1, n - 1] \cup \{v_n v_1\} \cup \{v_i v' ; i \in [1, n - 1] \cup \{v_n v'\} \cup \{v_{i+1} v'\}; i \in [1, n - 1] \cup \{v v'\}$. We distinguish two cases.

$i+1 \ 1 \ i \ 1 \ n$

Case 1 (odd n). First, We determine the lower bound of the locating chromatic number of $spl(C_n)$ for odd n . Since $spl(C_n)$ contains C_n , then by Theorem 1.2, we have $\chi_L(spl(C_n)) \geq 3$. For a contradiction, assume we have locating coloring using 3 colors. Let $\{c(v_i)\} = \{1, 2, 3\} = \{c(v^1)\}$.

Observe that vertex v^1 adjacent to vertex v_{i-1} and v_{i+1} , as well as vertex v_i adjacent to vertex v_{i-1} and v_{i+1} . Let vertex $v_j \in spl(C_n)$, with $j \neq \{i, i - 1, i + 1\}$. If $c(v^1) = c(v_j)$, then $c_\pi(v^1) = c_\pi(v_j)$.

Consequence, if $c(v^1) = c(v_i)$, then $c_\pi(v^1) = c_\pi(v_i)$, a contradiction. So, we have $\chi_L(spl(C_n)) \geq 4$.

To construct the upper bound of $spl(C_n)$. Let c be a vertex coloring using 4 colors like this 1, for $i = 1$

$$c(v_i) = \begin{cases} 2, & \text{for even } i \\ 3, & \text{for odd } i \end{cases} \\ c(v) = 4, \\ \text{for } 1 < i < n$$

For odd n the color codes of $V(spl(C_n))$ are:

$$c(v) = \begin{cases} i-1, & \text{for } 1^{st} \text{ component, } i \leq \frac{n+1}{2} \\ n-i+1, & \text{for } 1^{st} \text{ component, } i > \frac{n+1}{2} \\ \pi i \ 0, & \text{for } 2^{nd} \text{ component, even } i, 2 \leq i \leq n-1 \\ & \text{for } 3^{rd} \text{ component, odd } i, 3 \leq i \leq n \\ \{ 1, & \text{otherwise} \\ i-1, & \text{for } 1^{st} \text{ component, } 2 \leq i \leq \frac{n+1}{2} \\ n-i+1, & \text{for } 1^{st} \text{ component, } i > \frac{n+1}{2} \\ 0, & \text{for } 4^{th} \text{ component, } 1 \leq i \leq n \end{cases}$$

$$c_\pi(v) = \begin{cases} 2, & \text{for } 1^{st} \text{ component } i = 1 \\ & \text{for } 2^{nd} \text{ component, even } i, 2 \leq i \leq n-1 \\ & \text{for } 3^{rd} \text{ component, odd } i, 3 \leq i \leq n \\ \{ 1, & \text{otherwise} \end{cases}$$

Since all vertices in $spl(C_n)$ have distinct color codes, then c is a locating coloring. So,

$\chi_L(\text{spl}(C_n)) \leq 4$ for odd n .

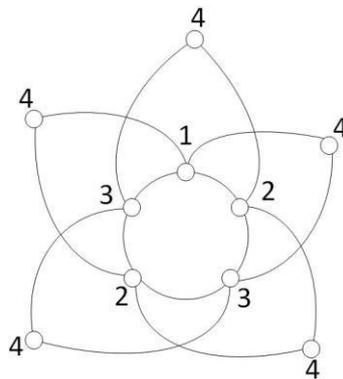


Figure 1. The minimum locating coloring of $\text{spl}(C_5)$.

Case 2 (even n). First, We determine the lower bound of the locating chromatic number of $\text{spl}(C_n)$ for even n . Since $\text{spl}(C_n)$ contains C_n for even n , then by Theorem 1.2, we have $\chi_L(\text{spl}(C_n)) \geq 4$. For a contradiction, assume we have locating coloring using 4 colors. Let $\{c(v_i)\} = \{1, 2, 3, 4\} = \{c(v^1)\}$.

Observe that vertex v^1 adjacent to vertex v_{i-1} and v_{i+1} , as well as vertex v_i adjacent to vertex v_{i-1} and v_{i+1} . Let vertex $v_j \in \text{spl}(C_n)$, with $j \neq \{i, i-1, i+1\}$. If $c(v^1) = c(v_j)$, then $c_\pi(v^1) = c_\pi(v_j)$. $i \ i$

Consequence, if $c(v^1) = c(v_i)$, then $c_\pi(v^1) = c_\pi(v_i)$, a contradiction. So, we have $\chi_L(\text{spl}(C_n)) \geq 5$

Let c be a vertex coloring and assign using 5 colors:

$$1, \quad \text{for } i = 1$$

$$c(v_i) = 2, \quad \text{for } i = 2$$

$$\{3, \quad \text{for odd } i$$

$$4, \quad \text{for even } i$$

$$3, \quad \text{for } i = 1$$

$$c(v_i) = \{4, \quad \text{for } i = n$$

$$5, \quad \text{for } 2 \leq i \leq n - 1$$

the color codes are:

$$i - 1, \quad \text{for } 1^{\text{st}} \text{ component, } i \leq \frac{n+1}{2}$$

$$n - i + 1, \quad \text{for } 1^{\text{st}} \text{ component, } i > \frac{n+1}{2}$$

$$i - 2, \quad \text{for } 2^{\text{nd}} \text{ component, } 2 \leq i \leq \frac{n+1}{2}$$

$$c_\pi(v_i) =$$

$$n - i + 2, \quad \text{for } 2^{\text{nd}} \text{ component } i > \frac{n+1}{2}$$

$$c_{\pi}(v_i) = \begin{cases} 0, & \text{for } 3^{rd} \text{ component, odd } i, 3 \leq i \leq n-1 \\ & \text{for } 4^{th} \text{ component, even } i, 4 \leq i \leq n \\ 2, & \text{for } 3^{rd} \text{ component } i=1 \\ & \text{for } 4^{th} \text{ component } i=2 \\ \{1, & \text{otherwise} \\ i-1, & \text{for } 1^{st} \text{ component, } 2 \leq i \leq \frac{n+1}{2} \\ n-i+1, & \text{for } 1^{st} \text{ component, } i > \frac{n+1}{2} \\ i, & \text{for } 2^{nd} \text{ component, } i=1 \text{ and } 2 \\ i-2, & \text{for } 2^{nd} \text{ component, } 3 \leq i \leq \frac{n+1}{2} \\ n-i+2, & \text{for } 2^{nd} \text{ component } i > \frac{n+1}{2} \end{cases}$$

$$c_{\pi}(v_i) = \begin{cases} \{ \\ 0, & \text{for } 3^{rd} \text{ component } i=1 \text{ for } 4^{th} \text{ component } i \\ =n & \text{for } 5^{th} \text{ component, } 2 \leq i \leq n-1 \\ \text{component } i=1 \\ & \text{for } 3^{rd} \text{ component, odd } i, 3 \leq i \leq n-1 \text{ for } 4^{th} \text{ component, even } i, 2 \leq i \leq n-2 \\ & \text{for } 3^{rd} \text{ component, odd } i, i=1 \text{ and } 2 \\ 1, & \text{otherwise} \end{cases}$$

Since for even n all vertices of $spl(C_n)$ have distinct color codes then c is a locating coloring. As a result, we have $\chi_L(spl(C_n)) \leq 5$. This concludes the proof. ■

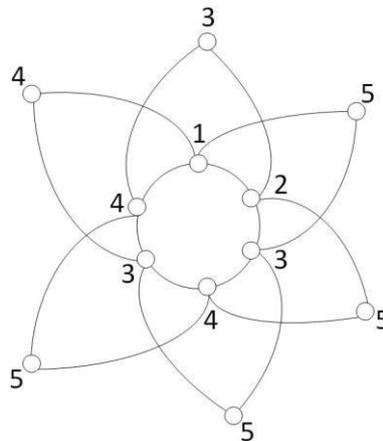


Figure 2. The minimum locating coloring of $spl(C_6)$.

3. Conclusions

Based on the result, to determine the locating chromatic number for split graph of cycle, by deviding two cases. The first case when odd n and second case when even

n . So that, obtained the locating chromatic number for split graph of cycle is $\chi_l(\text{spl}(C_n)) = 4$ for odd n and 5 for even n .

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PENGGUNAAN MULTIMEDIA BERBANTUAN TIK DALAM PENINGKATAN PEMAHAMAN KONSEP MATEMATIKA SISWA

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Abstrak

Perkembangan *Information and Communication Technology* (ICT) atau Teknologi Informasi dan Komunikasi (TIK) dalam beberapa dekade terakhir berjalan sangat cepat sejalan dengan perkembangan teknologi telekomunikasi, termasuk jaringan komputer. Berbagai teknologi dan aplikasi pendukung juga telah dikembangkan sebagai upaya untuk mendukung dan mempermudah aktivitas kehidupan manusia dan organisasi, termasuk kegiatan belajar mengajar dalam dunia pendidikan. Kehadiran dan kemajuan ICT di era komunikasi global dewasa ini telah memberikan peluang dan perluasan interaksi antara guru dan siswa, antar siswa, antara siswa dan sumber-sumber belajar dapat terjadi kapan saja dan di mana saja tanpa dibatasi oleh ruang dan waktu. Selain itu, dengan bantuan ICT proses penyampaian dan penyajian materi pembelajaran maupun gagasan dapat menjadi lebih menarik dan menyenangkan. Di sisi lain, kehadiran ICT sebagai teknologi baru memberikan tantangan kepada para guru untuk mampu menguasainya sehingga dapat memilih dan memanfaatkan ICT secara efektif dan efisien di dalam proses belajar mengajar yang dikelolanya. Multimedia salah satu inovasi yang dapat digunakan dalam pemenuhan kebutuhan bahan ajar suplemen. Penggunaan bahan ajar multimedia dapat meningkatkan kemampuan pemahaman konsep siswa.

Kata kunci: Multimedia, Pemahaman Konsep, TIK,

Abstract

The development of Information and Communication Technology (ICT) or Technology Information and Communication (TIK) in the last few decades has been running very fast in line with the development of telecommunications technology, including computer networks. Various supporting technologies and applications also have been developed as an effort to support and facilitate the activities of human life and organizations, including teaching and learning activities in the world of education. The presence and progress of

ICT in the current era of global communication has provided opportunities and expansion of interactions between teachers and students, between students, between students and learning resources can occur anytime and anywhere without being limited by space and time. In addition, with ICT the process of delivering and presenting learning materials and ideas can be more interesting and fun. On the other hand, the presence of ICT as a new technology challenges teachers to be able to master it so that they can choose and utilize ICT effectively and efficiently in teaching and learning process that they manage. Multimedia is one of the innovations that can be used in meeting the needs of supplementary teaching materials. The use of multimedia teaching materials can increase the ability to understand concepts on students.

Keywords: concept understanding, ICT, multimedia,



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PENDAHULUAN

Pendidikan bagi kehidupan manusia merupakan kebutuhan mutlak yang harus terpenuhi sepanjang hayat untuk memajukan kehidupan manusia itu sendiri. Pendidikan utamanya juga memiliki peran yang penting dalam pembangunan Nasional Indonesia. Menurut Susanto (2013: 121) salah satu disiplin ilmu yang berkaitan dengan pengetahuan dan pengembangan teknologi adalah matematika. Matematika dapat meningkatkan kemampuan berpikir dan memberikan kontribusi dalam masalah sehari-hari dan dalam dunia kerja, serta memberikan dukungan dalam pengembangan ilmu pengetahuan dan teknologi. Hal ini mengindikasikan bahwa matematika sebagai suatu mata pelajaran yang memiliki peranan cukup penting, baik pola pikir matematika dalam membentuk siswa menjadi berkualitas maupun kegunaannya dalam kehidupan sehari-hari, serta dengan menggunakan konsep dan prinsip matematika, membantu siswa untuk mengkaji masalah secara logis, kreatif, dan sistematis.

Gagne (Suherman, 2001) menyatakan, Matematika merupakan suatu disiplin ilmu yang mempunyai ciri atau karakteristik tertentu. Ciri-ciri tersebut di antaranya adalah *direct object* (objek langsung) dan *indirect object* (objek tidak langsung). Objek langsung matematika meliputi; fakta matematika, keterampilan matematika, konsep matematika dan prinsip matematika, sedangkan objek tidak langsung matematika meliputi; kemampuan berfikir logis, kemampuan memecahkan masalah, kemampuan berfikir analitis dan sikap positif terhadap matematika. Salah satu implikasi dari pandangan matematika sebagai kegiatan pemecahan masalah adalah guru harus membantu siswa mengetahui bagaimana dan kapan menggunakan berbagai media pendidikan matematika. Oleh karena itu perlu disusun sebuah skenario pembelajaran matematika yang mampu mengakomodasi implikasi tersebut agar tujuan tadi dapat terwujud.

Perkembangan *Information and Communication Technology* (ICT) atau Teknologi Informasi dan Komunikasi (TIK) dalam beberapa dekade terakhir berjalan sangat cepat sejalan dengan perkembangan teknologi telekomunikasi, termasuk jaringan komputer. Penggunaan TIK dalam dunia pendidikan saat ini sudah menjadi keharusan.

Menyikapi perkembangan dan kemajuan TIK tersebut, para guru dituntut untuk menguasai teknologi agar dapat mengembangkan materi-materi pembelajaran berbasis TIK dan memanfaatkan TIK sebagai media pembelajaran. Tujuannya adalah untuk memberikan kemudahan dan kesempatan yang lebih luas kepada pebelajar dalam belajar.

Menurut Susanto (2013: 121) salah satu disiplin ilmu yang berkaitan dengan pengetahuan dan pengembangan teknologi adalah matematika. Matematika dapat meningkatkan kemampuan berpikir dan memberikan kontribusi dalam masalah sehari-hari dan dalam dunia kerja, serta memberikan dukungan dalam pengembangan ilmu pengetahuan dan teknologi. Gagne (Suherman, 2001) menyatakan, Matematika merupakan suatu disiplin ilmu yang mempunyai ciri atau karakteristik tertentu. Ciri-ciri tersebut di antaranya adalah *direct object* (objek langsung) dan *indirect object* (objek tidak langsung). Objek langsung matematika meliputi; fakta matematika, keterampilan matematika, konsep matematika dan prinsip matematika, sedangkan objek tidak langsung matematika meliputi; kemampuan berfikir logis, kemampuan memecahkan masalah, kemampuan berfikir analitis dan sikap positif terhadap matematika. Salah satu implikasi dari pandangan matematika sebagai kegiatan pemecahan masalah adalah guru harus membantu siswa mengetahui bagaimana dan kapan menggunakan berbagai media pendidikan matematika. Oleh karena itu perlu disusun sebuah skenario pembelajaran matematika yang mampu mengakomodasi implikasi tersebut agar tujuan tadi dapat terwujud.

Konsep matematika merupakan ide abstrak yang memungkinkan seseorang untuk mengklasifikasi apakah suatu objek tertentu merupakan contoh atau non contoh dari ide abstrak tersebut (Suwarsono dan Sugiarto, 2008: 3). Pembentukan konsep dilakukan seperti belajar melalui penemuan. Proses pembentukan konsep merupakan proses induktif. Dalam pembentukan konsep, seseorang dihadapkan pada berbagai contoh maupun noncontoh dari suatu konsep kemudian melalui suatu proses, seseorang menentukan aturan atau kriteria untuk konsep tersebut.

Berlawanan dengan pembentukan konsep yang bersifat induktif, asimilasi konsep dilakukan dengan memberikan definisi formal suatu konsep terlebih dahulu. Menurut Rosser (Dahar, 2011:65), seseorang belajar melalui atribut-atribut kriteria konsep yang kemudian dihubungkan dengan gagasan-gagasan yang relevan yang ada pada struktur kognitif mereka. Setelah definisi suatu konsep diberikan, contoh atau diskripsi contoh verbal dapat digunakan untuk mengilustrasikan konsep tersebut.

Guru perlu mencari cara mengajar yang dapat merangsang siswa lebih aktif secara mandiri ataupun kelompok agar memahami suatu materi untuk mengatasi hal tersebut, Hasil survey yang dilakukan oleh Syamsuri (2010), sayangnya masih banyak guru yang menggunakan metode pembelajaran ceramah yang membuat siswa cenderung hanya menjadi pendengar yang pasif. Hal ini juga yang terjadi di salah satu sekolah negeri di Bandar Lampung yaitu SMP Negei 3 Bandar Lampung. Proses pembelajaran yang dilakukan oleh guru yang mengajar di sekolah tersebut kebanyakan masih menggunakan metode yang membuat siswa pasif. Akibatnya, banyak siswa mengalami kesulitan untuk menyelesaikan permasalahan dan tugas yang diberikan guru.

Observasi yang dilakukan di SMP Negeri 3 Bandar Lampung khususnya kelas VIII mendapatkan bahwa, Selama proses belajar, beberapa siswa dapat dengan mudah memahami materi yang diberikan. Namun masih banyak ditemui siswa yang melakukan kesalahan, kesalahan yang sering dilakukan siswa yaitu dalam hal membedakan antara garis singgung persekutuan dalam dengan garis singgung persekutuan luar. Siswa banyak mengalami kesulitan untuk menganalisis tentang posisi garis singgung persekutuan dalam atau persamaan garis singgung persekutuan luar. Dari kasus tersebut, terlihat bahwa siswa mengalami masalah pada konsep garis singgung yang dimilikinya sehingga cenderung melakukan kesalahan dalam menganalisis masalah garis singgung lingkaran yang diberikan.

Guru cenderung menggunakan metode ceramah dan pemberian masalah untuk diselesaikan oleh siswa kemudian secara bersama-sama menarik kesimpulan dalam proses pembelajaran garis singgung. Selain metode, setelah mengamati pembelajaran yang digunakan, terlihat tidak adanya media khususnya alat peraga garis singgung lingkaran yang digunakan guru selama proses pembelajaran berlangsung. Tidak tersedianya alat peraga tentang garis singgung lingkaran membuat siswa lebih sulit untuk memahami konsep garis singgung lingkaran karena siswa hanya mempelajari konsep abstrak tersebut tanpa dapat merealisasikannya secara nyata.

Media pembelajaran yang baik dan menarik juga dapat digunakan untuk menunjang proses pembelajaran selain penerapan metode pembelajaran yang tepat. Hasil penelitian Jacobs dan Schade (Munir, 2008) menunjukkan, daya ingat orang yang hanya membaca saja memberikan persentase terendah, yaitu 1%. Daya ingat ini dapat ditingkatkan hingga 25%-30% dengan bantuan media lain, seperti televisi. Daya ingat makin meningkat dengan penggunaan media 3 dimensi seperti multimedia, hingga 60%. Penelitian yang dilakukan oleh Putri (2011) didapatkan data sebanyak 81% siswa menyatakan bahwa penggunaan multimedia didalam proses pembelajaran memudahkan siswa dalam menerima pelajaran. Sebanyak 86% siswa menyatakan bahwa penggunaan multimedia didalam pembelajaran membantu meningkatkan minat belajar. Penelitian di atas menunjukkan, penggunaan multimedia dalam proses pembelajaran memberikan motivasi dan minat belajar yang baik serta membantu siswa dalam memahami materi yang diajarkan.

METODE PENELITIAN

Jenis penelitian ini adalah penelitian dan pengembangan (*research and development*) dengan mengikuti langkah-langkah Borg dan Gall yang mengacu pada prosedur Sanjaya (2013). Penelitian pengembangan adalah penelitian yang berorientasi untuk mengembangkan dan memvalidasi produk-produk yang digunakan dalam pendidikan. Produk yang akan dikembangkan pada penelitian ini adalah pengembangan Multimedia pembelajaran berbasis metode penemuan terbimbing untuk meningkatkan pemahaman konsep siswa. Langkah-langkah penelitian dan pengembangan ini dijelaskan sebagai berikut:

1. Studi Pendahuluan dan Pengumpulan Data

Langkah awal yang dilakukan pada studi pendahuluan adalah melakukan observasi dan wawancara terhadap guru matematika yang mengajar di sekolah dan terhadap beberapa orang siswa untuk mengetahui kesulitan apa saja yang sering dialami peserta didik dalam pembelajaran, kemudian menentukan model pembelajaran yang tepat untuk mengatasinya, sehingga dipilihlah model penemuan terbimbing berbantuan media pembelajaran. Selanjutnya melakukan studi literatur model penemuan terbimbing berbantuan media pembelajaran serta membuat desain pembelajarannya.

2. Perencanaan

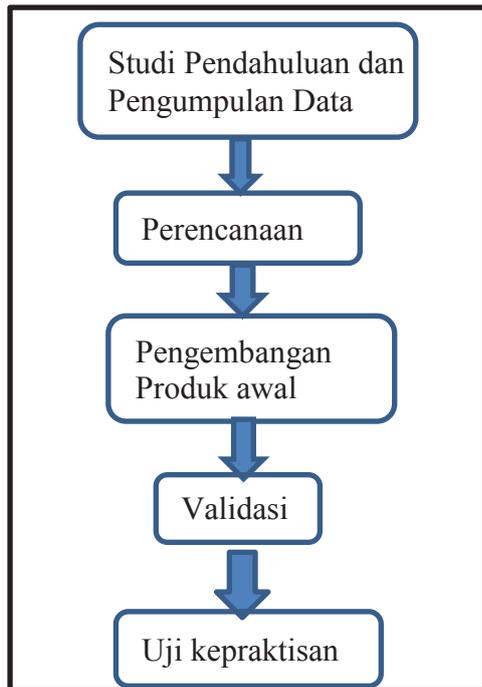
Penelitian ini dilakukan di SMP Negeri 3 Bandar Lampung. Subjek dalam penelitian ini adalah seluruh siswa kelas VIII C yang memiliki peserta didik 32 orang dan VIII D yang memiliki peserta didik 32 orang. Perencanaan selanjutnya adalah menyusun bahan ajar perangkat pendukung yang digunakan oleh guru dalam proses pembelajaran. Dalam model penemuan terbimbing berbantuan media pembelajaran, bahan ajar yang disiapkan diantaranya adalah silabus, RPP, dan LKPD. Materi yang disajikan adalah materi garis singgung lingkaran untuk siswa kelas VIII. Selanjutnya menyusun instrumen penilaian berupa lembar validasi baik kepada ahli materi maupun ahli media. Instrumen yang diberikan kepada guru berupa angket yang telah divalidasi oleh ahli materi dan ahli media.

3. Pengembangan Produk awal

Pada tahap ini, peneliti mulai membuat Multimedia pembelajaran serta desain pembelajaran.

4. Uji Coba

Multimedia berupa video garis singgung lingkaran yang telah dibuat divalidasi oleh pakar kemudian diuji cobakan kepada siswa. Kepada guru mata pelajaran matematika dan siswa diberikan angket kepraktisan instrument.



HASIL DAN PEMBAHASAN

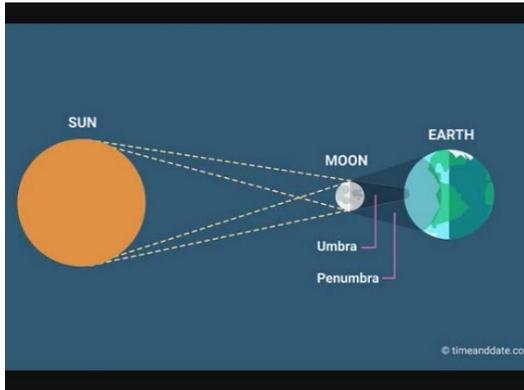
Produk yang dikembangkan dalam penelitian ini adalah multimedia pembelajaran berbantuan TIK. Hasil penelitian yang telah dilakukan dijabarkan sebagai berikut.

1. Studi Pendahuluan dan Pengumpulan Data. Studi pendahuluan dilakukan sebelum penelitian dilaksanakan, hal ini dilakukan untuk melihat masalah yang terjadi di lapangan.
2. Pengembangan multimedia.

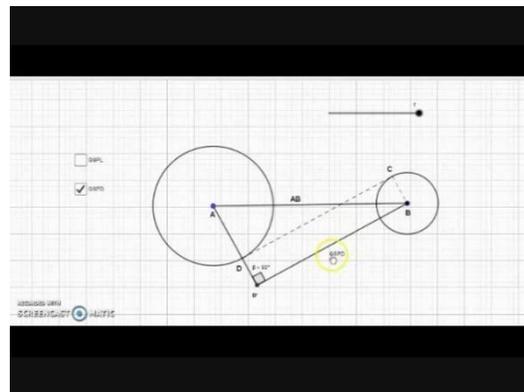
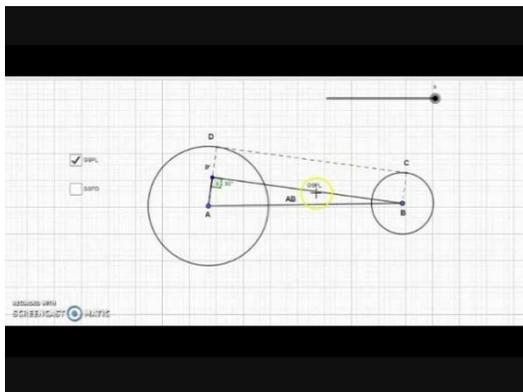
Langkah awal dalam pengembangan multimedia yang akan digunakan diawali dengan mengumpulkan materi yang akan dibahas. Selanjutnya mengumpulkan animasi penggunaan materi yang akan dipelajari, pada kehidupan sehari-hari. Langkah terakhir adalah membuat video atau animasi berisikan materi yang akan dipelajari. Secara garis besar multimedia yang dikembangkan terdiri dari:

- a) Bagian Pembukaan
Berisikan stimulus berupa animasi benda-benda disekitar yang berkaitan dengan materi yang akan dipelajari.
- b) Bagian Isi
Memuat video atau animasi tentang materi yang dipelajari
- c) Bagian Penutup
Ucapan Terimakasih dan Selamat Mengerjakan.

Berikut gambar multimedia yang dikembangkan.



Gambar 1. Tampilan pembukaan



Gambar 2. Tampilan inti multimedia



Gambar 3. Tampilan Penutup.

3. Hasil Validasi Ahli.

Analisis yang digunakan berupa deskriptif kualitatif dan kuantitatif. Data kualitatif berupa komentar dan saran dari validator dideskripsikan secara kualitatif sebagai acuan untuk memperbaiki silabus, RPP, dan LKPD dan Multimedia yang digunakan. Data kuantitatif berupa skor penilaian ahli materi dan ahli media dideskripsikan secara kuantitatif menggunakan skala likert dengan 4 skala kemudian dijelaskan secara kualitatif. Skala yang digunakan dalam penelitian pengembangan ini adalah 4 skala, yaitu.

- 1) Skor 1 adalah kurang baik.
- 2) Skor 2 adalah cukup baik.
- 3) Skor 3 adalah baik.
- 4) Skor 4 adalah sangat baik.

Berdasarkan data angket validasi yang diperoleh, rumus yang digunakan untuk menghitung hasil angket dari validator adalah sebagai berikut:

$$P = \frac{\sum X}{\sum X_i} \times 100\%$$

Keterangan :

P : Presentase yang dicari

$\sum X$: Jumlah nilai jawaban responden

$\sum X_i$: Jumlah nilai ideal

Sebagai dasar pengambilan keputusan untuk merevisi produk yang dikembangkan yaitu menggunakan kriteria penilaian yang dijelaskan pada Tabel 1. Arikunto (2009)

Persentase (%)	Kriteria Validasi
76-100	Valid
56-75	Cukup Valid
40-55	Kurang Valid
0-39	Tidak Valid

Tabel 1 Interpretasi Kriteria Penilaian Validitas Instrumen

Adapun hasil validasi instrument multimedia yang dikembangkan adalah:

Validator	Skor Aspek				Persentase
	1	2	3	4	
1	0	0	9	4	85%
2	0	0	8	5	83,3%
3	0	0	6	7	86,67

Tabel 2. Hasil validasi lembar validasi

4. Uji Coba Lapangan Awal

Data uji praktikalitas penggunaan Multimedia dianalisis dengan persentase (%), menggunakan rumus berikut ini.

$$\text{Nilai} = \frac{\sum \text{Skotperitem}}{\text{skormaksimumideal}} \times 100\%$$

Tabel 3. Kriteria Tingkat Praktikalitas Media Pembelajaran

Kriteria	Reng Presentase
Tidak Praktis	0- 20
Kurang Praktis	21-40
Cukup Praktis	41-60
Praktis	61-80
Sangat Praktis	81-100

Sumber: Riduwan (2010: 89)

Berikut ini hasil pengisian angket respon siswa oleh siswa kelas VIII SMP Negeri 3 Bandar Lampung pada uji coba terbatas.

Skor Diperoleh	Skor Ideal	Persentase Nilai
157	192	82%

Tabel 4. Angket respon siswa terhadap multimedia pembelajaran

Berdasarkan analisis skala respon menunjukkan bahwa instrumen multimedia pembelajaran memperoleh penilaian dengan kategori valid dan sangat praktis

Kekurangan dalam penelitian ini penelitian hanya dilaksanakan hingga tahapan uji kepraktisan. tidak adanya uji lapangan dikarenakan terkendala adanya pandemi covid 19, sehingga mengakibatkan tidak ada yang menjamin apakah penelitian yang akan dilakukan di kelas nantinya sesuai dengan kriteria yang telah ditentukan. Namun berdasarkan faktor-faktor yang diuraikan di atas dapat disimpulkan bahwa, pengembangan multimedia berbantuan multimedia efektif dalam meningkatkan kemampuan pemahaman konsep siswa. Hal ini terjadi karena menurut pendapat ahli, pendapat siswa pada ujicoba lapangan awal pada proses pembelajaran menggunakan multimedia berbantuan TIK memuat indikator pemahaman konsep yang mampu mengakibatkan keefektifan dan kepraktisan dalam proses pembelajaran dengan metode tersebut

KESIMPULAN DAN SARAN

Simpulan

Berdasarkan hasil penelitian dan pembahasan secara keseluruhan dapat diambil kesimpulan sebagai berikut:

1. Pengembangan multimedia berbantuan TIK untuk meningkatkan pemahaman konsep peserta didik, diawali dari studi pendahuluan yang menunjukkan adanya kebutuhan untuk dikembangkannya Multimedia. Hasil validasi menunjukkan bahwa Multimedia berbantuan TIK pada materi lingkaran telah layak digunakan dan termasuk dalam kategori sangat baik.
2. Hasil penelitian pengembangan Multimedia berbantuan TIK yang dilaksanakan hingga tahap uji kepraktisan menunjukkan bahwa instrument yang telah

dikembangkan valid dan praktis, Sehingga instrument yang dikembangkan dapat digunakan dalam proses pembelajaran untuk mendapatkan pencapaian ketuntasan belajar yang lebih baik, Hal ini terjadi karena menurut pendapat ahli, pendapat siswa pada ujicoba lapangan awal serta pendapat guru matapelajaran pada proses pembelajaran menggunakan multimedia berbantuan TIK memuat indikator pemahaman konsep yang mampu mengakibatkan keefektifan dan kepraktisan dalam proses pembelajaran dengan metode tersebut.

Saran

Berdasarkan kesimpulan dan hasil penelitian yang telah dilakukan maka saran-saran yang dapat diberikan adalah sebagai berikut:

1. Guru dapat menjadikan Multimedia berbantuan TIK sebagai referensi dalam meningkatkan kemampuan pemahaman konsep matematis peserta didik pada materi-materi lain disetiap jenjang pendidikan.
2. Penelitian Pengembangan Multimedia berbantuan TIK dapat dijadikan inspirasi bagi pengembangan perangkat pembelajaran mata pelajaran lainnya karena telah terbukti efektif dalam meningkatkan kemampuan pemahaman konsep peserta didik.
3. Penggunaan Multimedia berbantuan TIK ini hendaknya dikolaborasikan dengan metode pembelajaran yang baik agar tercipta pembelajaran yang lebih bervariasi. Perlu dilakukan penelitian lebih lanjut dalam waktu yang lebih lama agar didapat hasil peningkatan kemampuan pemahaman konsep matematis yang lebih signifikan

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MODELING MULTIVARIATE TIME SERIES BY VECTOR ERROR CORRECTION MODELS (VECM) (STUDY: PT KALBE FARMA TBK. AND PT KIMIA FARMA (PERSERO) TBK)

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Abstract

Time series analysis (time series) is one method with the aim to find out events that will occur in the future based on data and past circumstances. Time series are widely used in economics, business, environmental science, and finance. The analytical tool that is widely used to answer quantitative research problems is the Autoregressive Vector (VAR). The VAR model is used if the data is stationary. If the variable has cointegration and stationary at the first difference value, the VAR model is modified to become the Error Correction Model (VECM). Then we can find out the influence of variables with other variables by looking at the Impulse Response Function and Granger Causality. In this research, PT Kalbe Farma Tbk's stock data will be analyzed. (KLBF) and PT Kimia Farma (Persero) Tbk (KAEF). The data used are weekly data from January 2010 to June 2020. Based on data analysis, it is known that the data is not stationary and there are unit roots. Furthermore, first differencing is done to make the data stationary. Because there was cointegration, a VECM analysis was performed and a VECM (p) was obtained with a lag of $p = 4$. So the best model for this research is VECM (4) with rank = 2. Causal relationships between variables using Granger Causality showed that KLBF influenced KAEF in the past. Based on IRF analysis, each variable gives a fluctuating response with itself and with other variables.

Keywords: VAR model, VECM, cointegration, Granger Causality, Impulse Response Function

1. Introduction

Time series analysis is one method with the aim to find out events that will occur in the future based on data and past circumstances. In general, the time series econometrics model is a structural model because it is based on existing economic theories. In 1980 Christopher A. Sims introduced the VAR model as an alternative in macroeconomic analysis. The analytical tool commonly used to answer quantitative research problems is the Autoregressive Vector (VAR). The VAR model is used to explain the simultaneous variables that have influence on each other. The VAR model is used if the data is stationary at the level. The data is not stationary at the level but stationary at the first difference value we will use the Autoregressive Vector in Difference (VARD) if all variables do not have



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Published under licence by IOP Publishing Ltd cointegration. When the variables have cointegration and stationary at the first difference value, then the Error Correction Model (VECM) is used. In this applied statistical research various cases of multivariate time series data will be examined. Modeling that will be used for multivariate time series data is the Error Correction Model (VECM) Vector, which will then be seen the causal relationship between time series variables using Granger Causality, to see the effect of the shock of a variable against other variables will be used Impulse Response Function (IRF)). Discussed the relationship and forecasting between the price indexes of two oil companies in Indonesia using VAR [1].

In this research, modeling will be carried out on the stock data of PT Kalbe Farma Tbk. (KLBF) and PT Kimia Farma (Persero) Tbk (KAEF). PT Kalbe Farma Tbk., with its subsidiaries, develop, manufacture, and trade pharmaceutical products in Indonesia. It operates in four segments: Prescription Pharmacy, Consumer Health, Nutrition, and Distribution and Logistics. The company was founded in 1966 and based in Jakarta, Indonesia. PT Kalbe Farma Tbk. is a subsidiary of PT Gira Sole Prima. PT Kimia Farma (Persero) Tbk manufactures and sells medicines, herbal medicines, iodine, salt, quinine and its derivative products, and vegetable oils in Indonesia, throughout Asia, Europe, Australia, Africa and New Zealand. The company operates through the manufacturing, distribution, retail and other services segments. The company was founded in 1817 and based in Jakarta, Indonesia. Both of these variable data are time series data. So that time series analysis can be done to make multivariate modeling that can be used for the future. The objectives of this study are (1) Formulating a Multivariate Time series data model with the Vector Error Correction Model (VECM) approach. (2) Review the behavior of Multivariate data with Granger Causality. (3) Assess how the behavior of one variable with respect to other variables in the event of shock and how long the equilibrium will occur.

2. Literature Review

2.1 Test Cointegration

The concept of cointegration was introduced by Engle and Granger and the development of practical and inferential estimation methods was given by Johansen. In much of the literature, the time series X_t is said to be integrated with the sequence process 1, $I(1)$, if $(1-B)X_t$ is stationary and cannot be reversed. If the time series data is stationary and can be reversed, it says process $I(0)$. In general, univariate time series X_t is process $I(d)$, if $(1-B)^d X_t$ stationary and non invertable [2],[3],[4]. Burke and Hunter proposed the procedure of Johansen's for estimation and inferencial [5]. If there is cointegration between variables, then we must test the cointegration ranking. Some cointegration rank testing methods are as follows: Trace test and Test the maximum eigenvalue. In the cointegration test Johansen cointegration test is used as follows: It is known that the model $VAR(p)$ is

$$y_t = Ay_{t-1} + \dots + Apy_{t-p} + Bx_t + \varepsilon_t$$

where y_t is a vector with k non stationary variable $I(1)$, x_t is a vector with d deterministic variable, ε_t is an error vector. The equation $VAR(p)$ can also be written as

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + Bx_t + \varepsilon_t$$

where

$$\Pi = \sum_{i=1}^p A_i + I, \quad \Gamma_i = -\sum_{j=1}^p A_j$$

For testing the hypotheses can be used the trace test :

$$LR_{tr}(r|k) = -T \sum_{i=r+1}^k \log(1 - \lambda_i)$$

And statistical test for maximum eigen value

$$\begin{aligned} LR_{max}(r|r+1) &= -T \log(1 - \lambda_{r+1}) \\ &= LR_{tr}(r|k) - LR_{tr}(r+1|k) \end{aligned}$$

for $r = 0, 1, \dots, k-1$, with the null hypotheses is H_0 ; there is r cointegration equation.

At the significance level $(1 - \alpha) 100\%$, H_0 is accepted if the trace test statistic and the maximum eigenvalue are smaller than the critical value when α , or p -value is greater than the significance value α [6]. If there is cointegration between variables, the representation the error-correction VAR model was modified, so the model became a VECM model [7] [8].

2.2 Vector Autoregressive (Var)

Vector Autoregressive (VAR) is a special form of simultaneous equation system. The VAR model can be applied if all variables used are stationary, but if the variables in the Y_t vector are not stationary then the model used is the Vector Error Correction

Model (VECM) provided that there is one or more cointegration relationships between the variables. VECM is a limited VAR that is designed to be used in non-stationary data which is known to have a cointegration relationship [9].

$$y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + \varepsilon_t$$

where,

y_t : is vector of observation,

A : matrix of parameter,

ε_t : vektor error

If the data used is stationary at the same differencing level and there is cointegration, then the VAR model will be combined with the error correction model into the Vector Error Correction Model (VECM) [7].

2.3 Vector Error Correction Model (VECM)

VECM is a limited VAR model designed to be used in non-stationary time series but has a cointegration relationship between variables. VECM is very useful because it can estimate the shortterm effects between variables and the long-term effects of time series data. The general form of VECM (p) where p is the lag of endogenous variables with cointegration rank $r \leq k$ is as follows [2]:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_t + D_t + \varepsilon_t - \dots - i$$

where:

Δ = operator differencing, where $\Delta y_t = y_t - y_{t-1}$, $y_{t-1} =$

vector variable endogenous with lag 1,

ε_t = $k \times 1$ vector residuals,

D_t = $k \times 1$ vektor constant,

Π = matrix coefficient of cointegration ($\Pi = \alpha \beta^t$; α = vector adjustment, $k \times r$ matrix and β = matrix cointegration (long-run parameter) ($k \times r$)) Γ_i = $k \times k$ matrix coefficient the i th variable endogenous.

2.4 Test For Normality Of Residuals

Residual normality test is used to determine the residual normality in a multivariate model. The normality test is carried out using the Jarque-Bera (JB) Test of Normality. This test uses a measure of skewness and kurtosis. Jarque-Bera (JB) used in the normality test on the residual model where the calculation is done by adding indicators of the number of independent variables or predictors, JB calculation is as follows:

$$JB = \left[\frac{N}{6} b_1^2 + \frac{N}{24} (b_2 - 3)^2 \right]$$

Where:

N = number of sample size,

b_1 = Expected Skewness

b_2 = Expected Excess Kurtosis

where Jarque-Bera (JB) Test of Normality with chi-square χ^2 distribution with degrees of freedom 2 [10].

2.5 Granger Causality

Granger causality is used to see short-term relationships in the form of reciprocity between variables in a vector. A stable VAR is defined as follows:

$$y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} A_{11,1} & A_{12,1} \\ A_{21,1} & A_{22,1} \end{bmatrix} \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \end{bmatrix} + \dots + \begin{bmatrix} A_{11,p} & A_{12,p} \\ A_{21,p} & A_{22,p} \end{bmatrix} \begin{bmatrix} y_{1t-p} \\ y_{2t-p} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix}$$

y_t is consist of vector y_{1t} and y_{2t} . y_{2t} is not grager causality for y_{1t} if coefficient matrix of parameter VAR namely $A_{21,i} = 0$ for $i=1,2,\dots, p$ [2].

The Granger Causality Test is based on the F test which attempts to determine if there is a change in one variable due to a change in another variable. A variable X is said to be a Granger Cause variable Y, if the previous value of X can predict the current Y value.

VAR Model:

$$y_t = \sum_{i=1}^p \phi_i y_{t-i} + \varepsilon_t$$

If all the coefficients ϕ on the lag value of y are significant then X Granger Causal Y. If X Granger Causal Y and not vice versa, it is called indirect causality. If causality is found in both, from X to Y and from Y to X, then it is called bidirectional causality [11] [12] [13].

2.6 Impulse Response Function (IRF)

The Impulse Response Function is a method used to see the response of an endogenous variable to shock given by another variable. A Vector Autoregressive (VAR) can be written in the form of a Vector Moving Average (VMA) that allows us to see various responses from variable in the VAR system. The VAR model can be written in the MA vector (∞) as

And the matrix has an interpretation as follows:

$$X_t = \mu + \mu_1 + \Psi_1 \mu_{t-1} + \Psi_2 \mu_{t-2} + \dots$$

$$\frac{\partial X_{t+s}}{\partial u_t} = \Psi_s$$

Row i , column j element identifies the consequence of increasing one unit in the innovation of variable j on the date t (μ_{jt}) for the value of the i variable at time $t + s$ (X_{it+s}), holding all other innovations at all constant dates. If the first μ_t element is changed by δ_1 , at the same time, the second element is changed by δ_2 , ..., and element n by δ_n , then the combined effect of this change on the vector value X_{t+s} will

$$\Delta X_{t+s} = \frac{\partial X_{t+s}}{\partial u_{1t}} \delta_1 + \frac{\partial X_{t+s}}{\partial u_{2t}} \delta_2 + \dots + \frac{\partial X_{t+s}}{\partial u_{nt}} \delta_n = \Psi_s \delta$$

Plot of row i , column j element of Ψ_s is called Impulse Response Function (IRF).

3. Results And Discussion

The first step that must be passed to get the VECM estimate is to test the stationarity of each variable's data. Stationary data is needed to influence the results of the VECM estimation test. In this study, to detect whether or not the stationary variable of each variable data, it can be seen with a time series plot, ACF graph (Autocorrelation Function), and Augmented Dickey-Fuller Unit Root Test.

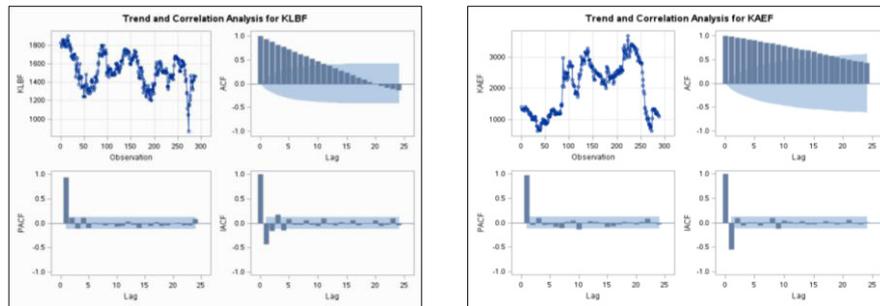


Figure 2 Trend and correlation analysis for KLBF and for KAEF

Table 1. Augmented Dickey Fuller Unit Roots Test

Variable	Type	lags	ρ	Pr < ρ	Tau	Pr < Tau
Kurs KLBF	Zero mean	3	-0.4354	0.5837	-0.68	0.4204
	Single mean	3	-19.7479	0.0113	-3.20	0.0215
	trends	3	-21.6944	0.0454	-3.26	0.0747
Kurs KAEF	Zero mean	3	-0.6201	0.5441	-0.58	0.4652
	Single mean	3	-3.7952	0.5605	-1.32	0.6227
	trends	3	-2.7430	0.9466	-0.85	0.9589

From Figure 1, the time series plot shows that the two variables above are not stationary because they still contain elements of trend. Furthermore, the instability of the data is also shown by the ACF graph where from lag 1 to the next lag falls slowly linearly near zero, this shows that the coefficient of autocorrelation is significantly different from zero. From table 1, all variables contain unit roots or are not stationary at the level. This can be seen in the p value of the statistical value Tau (τ) all types of testing for each variable is greater than the significance limit used, namely $\alpha = 0.05$, so the data is not stationary (there is a unit root). Thus it can be said that all the variables above contain unit roots or are not stationary. Since all variables are not stationary at the level level, the first differencing is performed on the data, then checked again using time series plots, ACF charts and unit root tests.

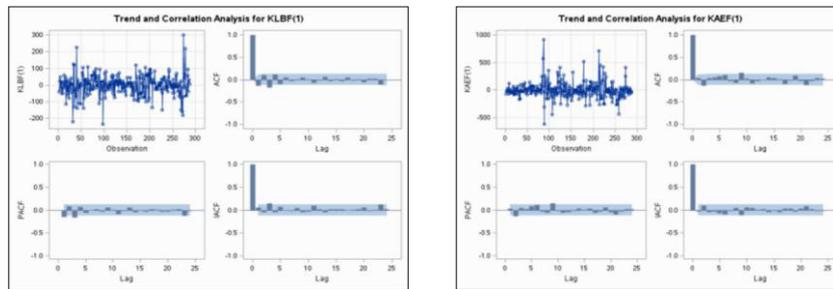


Figure 2 Trend and correlation analysis for KLBF and for KAEF

Table 2. Augmented Dickey Fuller Unit Roots Test

Variable	Type	lags	ρ	Pr < ρ	Tau	Pr < Tau
Kurs KLBF	Zero mean	3	-462.644	0.0001	-11.24	<.0001
Single mean trends	3	3	-464.561	0.0001	-11.23	<.0001
	3	3	-466.902	0.0001	-11.23	<.0001
Kurs KAEF	Zero mean	3	-305.689	0.0001	-9.91	<.0001
Single mean trends	3	3	-305.725	0.0001	-9.89	<.0001
	3	3	-314.081	0.0001	-9.97	<.0001

From Figure 2 in the time series plot it can be seen that the two variables are stationary to the mean and variance because they no longer contain an element of trend. Furthermore, the stationarity of the data is also shown by the ACF graph where from lag 0 to the next lag it slowly decreases exponentially to zero. So it can be concluded that the five variables above are stationary to the mean and variance. From Table 2, all variables no longer contain unit or stationary roots in the 1st Differencing. This can be seen in the p value of statistical Tau all types of testing for each variable is smaller than the significance limit used, $\alpha = 0.05$, so that the data is stationary (there is no unit root). Thus it can be said that all of the above variables do not contain unit roots or stationary data.

3. 1 Test for Lag Optimal

VECM estimates are very sensitive to the lag length of the data used. The length of the lag is used to determine the time needed for the effect of each variable on its past variable. In this study, determining the length of the lag is done by looking at the smallest value of the information criteria. Determination of the optimum lag as follows:

Table 3. Lag Optimal

Information criterion	VAR(1)	VAR(2)	VAR(3)	VAR(4)	VAR(5)
AICC	17.36952	17.36942	17.3686	17.35107*	17.36112
HQC	17.38788*	17.39994	17.41118	17.40565	17.42762
AIC	17.36939	17.36908	17.36793	17.34995*	17.35944
SBC	17.41668*	17.448	17.47856	17.4924	17.53379
FPEC	34948784	34938002	34897684	34276010*	34603014

Based on table 3, it can be seen that the optimal lag length lies in lag 4. The selection of lag 2 as the optimal lag is based on the smallest values of AICC, AIC, and FPEC. So cointegration testing will be carried out in lag 4.

3.2 Test Cointegration

Cointegration testing is used to determine the long-term relationship of each variable. The requirement in estimating VECM is that there is a cointegration relationship in it. If there is no cointegration relationship, then the VECM estimate is canceled, but must use the VAR (Vector Autoregression) model. The cointegration test used in this study is the Johansen cointegration test.

Table 4. Table cointegration

$H_0: \text{Rank}=r$	$H_1: \text{Rank}>r$	Eigenvalue	Trace	Pr > Trace
0	0	0.1979	227.9709	<.0001
1	1	0.1807	108.2325	<.0001

ased on Table 4, it can be seen that the p value for rank = 1 is smaller than the significance limit used, namely $\alpha = 0.05$, so there is not enough evidence to reject $H_1: \text{rank} > r$. Thus it can be said that there is a cointegration relationship between variables with rank = 2. Because the data used there is a cointegration relationship, the VAR (p) model used is VECM (p) with rank = 2.

3.3 Selection of VECM(p)

Selection of VECM(p) based on the information criterion of AICC, HQC, AIC, SBC and FPEC, the best VECM(p) is as follows:

Table 5. Selection VECM(p)

Information criterion	VECM(1)	VECM(2)	VECM(3)	VECM(4)	VECM(5)
AICC	17.36952	17.36942	17.3686	17.35107*	17.36112
HQC	17.38788*	17.39994	17.41118	17.40565	17.42762
AIC	17.36939	17.36908	17.36793	17.34995*	17.35944
SBC	17.41668*	17.448	17.47856	17.4924	17.53379
FPEC	34948784	34938002	34897684	34276010*	34603014

Based on Table 5 it can be seen that the smallest values of AICC, AIC, and FPEC are found in VECM (4). So that VECM (4) was chosen as the best model.

3.4 The estimation Parameter of VECM(4) with rank $r=2$

Based on the above analysis, VECM (4) was selected as the best model with rank $r = 2$. Next, we will estimate the model for VECM (4) as follows:

Table 6. Long-Run Parameter Beta
Estimates when RANK=2

Variable	1	2
KLBF	0.04208	0.01324
KAEF	-0.00844	0.01620

Table 7. Adjustment Coefficient Alpha
Estimates When RANK=2

Variable	1	2
KLBF	-23.09162	-10.51971
KAEF	14.39345	-50.96496

Table 8. Parameter Alpha

Variable	KLBF	KAEF
KLBF	-1.11094	0.02450
KAEF	-0.06902	-0.94739

Table 9. Model Parameter Estimates

Equation	Parameter	Estimate	Standard Error	t Value	Pr > t	Variable
D_KLBF	AR1_1_1	-1.11094	0.09739			KLBF(t-1)
	AR1_1_2	0.02450	0.04034			KAEF(t-1)
	AR2_1_1	0.00790	0.08104	0.10	0.9224	D_KLBF(t-1)
	AR2_1_2	0.00962	0.03526	0.27	0.7851	D_KAEF(t-1)
	AR3_1_1	-0.02219	0.06415	-0.35	0.7296	D_KLBF(t-2)
	AR3_1_2	-0.03383	0.02925	-1.16	0.2479	D_KAEF(t-2)
	AR4_1_1	-0.13230	0.04263	-3.10	0.0020	D_KLBF(t-3)
	AR4_1_2	-0.05164	0.02018	-2.56	0.0108	D_KAEF(t-3)
D_KAEF	AR1_2_1	-0.06902	0.21217			KLBF(t-1)
	AR1_2_2	-0.94739	0.08788			KAEF(t-1)
	AR2_2_1	0.11690	0.17653	0.66	0.5081	D_KLBF(t-1)
	AR2_2_2	-0.08981	0.07681	-1.17	0.2428	D_KAEF(t-1)
	AR3_2_1	-0.02170	0.13974	-0.16	0.8767	D_KLBF(t-2)
	AR3_2_2	-0.04961	0.06371	-0.78	0.4365	D_KAEF(t-2)
	AR4_2_1	-0.00970	0.09288	-0.10	0.9168	D_KLBF(t-3)
	AR4_2_2	-0.04136	0.04396	-0.94	0.3472	D_KAEF(t-3)

Based on the parameter estimation results, the VECM estimation (4) is obtained, i.e.

$$\Delta Y_t = \Pi Y_{t-1} + \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \Gamma_1 \Delta Y_{t-3} + \varepsilon_t$$

$$\Delta Y_t = \begin{bmatrix} -1.11094 & 0.02450 & 0.00790 & 0.00962 \\ -0.06902 & -0.94739 \end{bmatrix} Y_{t-1} + \begin{bmatrix} 0.11690 & -0.08981 \end{bmatrix} \Delta Y_{t-1} - 0.02219 \Delta Y_{t-2} - 0.03383 \Delta Y_{t-3} + \begin{bmatrix} -0.02170 & -0.04961 \end{bmatrix} \Delta Y_{t-2} + \begin{bmatrix} -0.13230 & -0.05164 \\ -0.00970 & -0.04136 \end{bmatrix} \Delta Y_{t-3} + \begin{bmatrix} \varepsilon_{t1} \\ \varepsilon_{t2} \end{bmatrix}$$

Table 10. Schematic Representation of Cross Correlations of Residuals

Variable/Lag	0	1	2	3	4	5	6	7	8	9	10	11	12
KLBF	++
KAEF	++

+ is > 2*std error, - is < -2*std error, . is between

Table 11. Portmanteau Test for Cross Correlations of Residuals

Up To Lag	DF	Chi-Square	Pr > ChiSq
5	4	5.86	0.2099
6	8	8.06	0.4272
7	12	9.46	0.6636
8	16	17.40	0.3604
9	20	24.82	0.2082
10	24	25.74	0.3663
11	28	26.92	0.5227
12	32	30.73	0.5308

3.5 Normality Residual

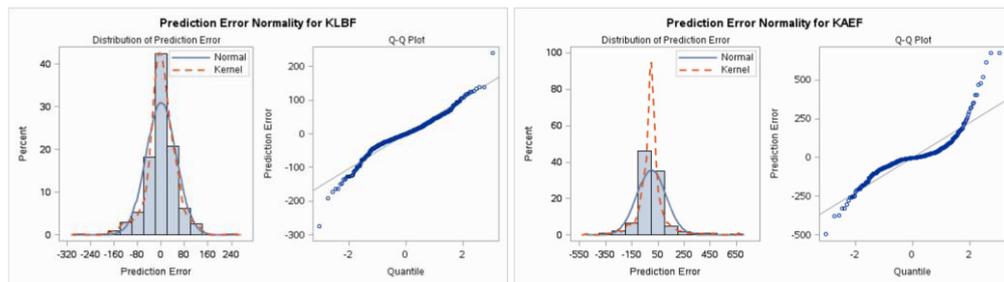


Figure 3. Prediction Error Normality for KLBF and for KAEF

Table 12. Univariate Model White Noise Diagnostics

Variable	Durbin	Normality	ARCH	Watson
	Chi-Square	Pr > ChiSq	F Value	Pr > F
KLBF	1.98909	241.34	<.0001	4.57 0.0330
KAEF	2.00446	2234.35	<.0001	41.99 <.0001

Table 13. Univariate Model AR Diagnostics

Variable	AR1		AR2		AR3		AR4	
	F Value	Pr > F						
KLBF	0.02	0.8993	0.01	0.9877	0.03	0.9941	0.03	0.9986
KAEF	0.00	0.9566	0.00	0.9976	0.00	0.9999	0.00	1.0000

Tables 12 and 13 are used to examine residual white noise on the condition of a univariate equation. The table shows a statistical test for distribution normality using the Jarque Bera normality test. Table 12 shows the p-values for KLBF and KAEF <0.05, meaning that the residuals are normally distributed. From Figure 3 it can be seen that the residual is approaching the normality line.

3.6 Test for Stability Model

The model stability test is used to see whether the model is stable or not.

Table 14. Roots of AR Characteristic Polynomial

Index	Real	Imaginary	Modulus	Radian	Degree
1	0.48209	0.03817	0.4836	0.0790	4.5274
2	0.48209	-0.03817	0.4836	-0.0790	-4.5274
3	0.04416	0.65159	0.6531	1.5031	86.1226
4	0.04416	-0.65159	0.6531	-1.5031	-86.1226
5	-0.00620	0.38205	0.3821	1.5870	90.9301
6	-0.00620	-0.38205	0.3821	-1.5870	-90.9301
7	-0.50635	0.00000	0.5064	3.1416	180.0000
8	-0.67399	0.00000	0.6740	3.1416	180.0000

Based on Table 14, you can see the modulus value <1. So that VECM (4) is a model that is feasible to use.

3.7 Test for fit the Model

The model fit test can be seen from the ANOVA table of the univariate model to determine the significance of the model. Based on the equation of the VECM model (4) written univariately, the model feasibility test is as follows:

Table 15. Univariate Model ANOVA Diagnostics

Variable	R-Square	Standard Deviation	F Value	Pr > F
KLBF	0.5688	48.41149	32.32	<.0001
KAEF	0.5423	18.57153	29.03	<.0001

Based on Tabel 15, the univariate F-test are 32.32 and 29.03 with p-values <0.0001 for both KLBF and KAEF respectively.

3.8 Analisis of Granger-Causality

Granger-Causality Test is intended to determine the causal relationship of each independent variable on the dependent variable. The Granger-Causality test is based on the wald-test with the chi-square distribution or F-test. The null hypothesis in the Granger-Causality test is where group one is influenced by itself not by group two.

Table 16. Granger Causality Wald Test

Test	Group Variables	Pr > ChiSq	Conclusion
1	Group 1 Variables : KLBF Group 2 Variables : KAEF	0.0056	Reject H ₀
2	Group 1 Variables : KAEF Group 2 Variables : KLBF	0.5926	Not enough evidence to reject H ₀

Based on table 16, in test 1, the p-value <0.05 reject H₀ means that KLBF is affected by KAEF. In test 2, p-value > 0.05 was obtained, it means that there was not enough evidence to reject H₀. So in the second test, KAEF is affected only on itself and not on KLBF.

3.9 Impulse Response Function (IRF)

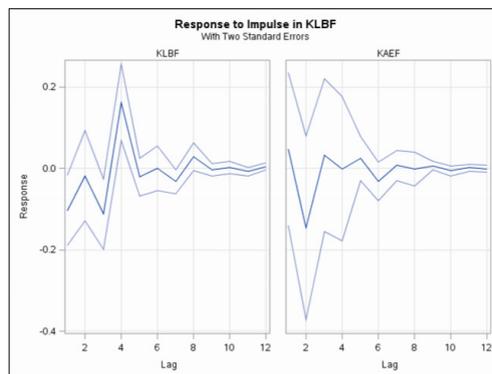


Figure 4. Response to Impulse in KLBF

Based on Figure 4, if the Impulse Response Function (IRF) graph experiences a shock of one standard deviation it will affect the KAEF variable and itself. If the IRF chart approaches the point of equilibrium or returns to the zero line, it means that the

response of the variable to show other variables is getting lost so that the shock does not leave a permanent effect on the variable. Shock one standard deviation at ITMA, because ITMA gives a fluctuating response from the first week to the ninth week. In the first week to the second week the response is negative. The third and fourth weeks provide positive responses. The fifth and sixth week gives positive responses. The seventh and eighth week gives positive responses. The ninth week onwards the response begins to approach the point of balance and positive response. Shock one standard deviation at ITMA, because ELSA gives a positive fluctuating response from the first week to the seventh week. In the first week and second week negative responses. In the third week and the fourth week the value dropped but the response was positive. In the fifth week and the sixth week the response is negative. Then in the seventh week it starts to strike a balance point.

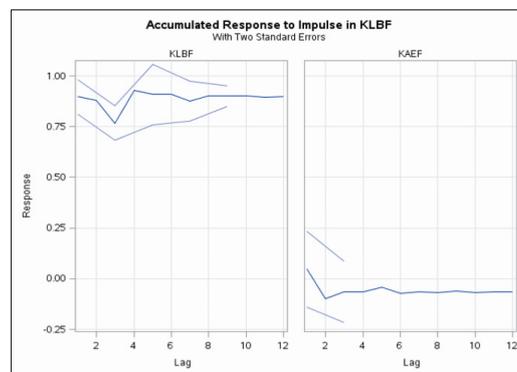


Figure 5. Response to Impulse in KAEF

Based on Figure 5, if the Impulse Response Function (IRF) graph experiences a shock of one standard deviation it will affect the KAEF variable and itself. If the IRF chart approaches the point of equilibrium or returns to the zero line, it means that the response of the variable to show other variables is getting lost so that the shock does not leave a permanent effect on the variable. Shock one standard deviation at KAEF, because KLBF gives a fluctuating response from the first week to the third week. Then in the fourth week onwards it does not fluctuate and gives a positive response because it is above point 0. Shock one standard deviation at KLBF, because KAEF gives a fluctuating response from the first week to the third week. Then in the fourth week and so on it does not fluctuate but gives a negative response because it is below the 0 point.

4. Conclusion

Based on the analysis of KLBF and KAEF time series data per week during January 2010-June 2020. This study examines the relationship between KLBF and KAEF, there is a cointegration relationship between KLBF and KAEF stock data with rank = 2. Based on the cointegration test and the smallest value of the information criteria, the best model is VECM (p) with lag p = 2. Meanwhile, the granger causality test explains that in test one a p-value of <math><0.05</math> starting with H_0 means that KLBF is affected by KAEF. Whereas in the second test, there was not enough evidence to reject H_0 , meaning that KAEF stock data

was affected only by itself and not by KLBF stock data. Based on IRF analysis, each variable gives a fluctuating response with itself and with other variables.

Acknowledgements

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THE LOCATING CHROMATIC NUMBER OF SOME MODIFIED PATH WITH CYCLE HAVING LOCATING NUMBER FOUR

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Abstract

The locating-chromatic number was introduced by Chartrand in 2002. The locating-chromatic number of a graph is a combined concept between the coloring and partition dimension of a graph. The locating chromatic number of a graph G is defined as the cardinality of minimum color classes. In this paper, we discuss about the locating chromatic number of three types modified path with cycle having locating chromatic number four.

Keyword: *locating chromatic number, path, cycle.*

1. Introduction

The locating-chromatic number of a graph is a combined concept between the coloring and partition dimension of graph. Chartrand et al. has been introduced the concept of the partition dimension of a graph in 1998 [2] and the concept of locating chromatic number of a graph in 2002 [1].

Let $G = (V, E)$ be a connected graph. Let c be a proper k -coloring of G with colors $1, 2, \dots, k$. Let $\pi = \{C_1, C_2, \dots, C_k\}$ be a partition of $V(G)$, where C_i is the set of vertices receiving color i . The color code $C_\pi(v)$ of v is the ordered k -tuple $(d(v, C_1), d(v, C_2), \dots, d(v, C_k))$ where $d(v, C_i) = \min\{d(v, x) | x \in C_i\}$ for any i . If all distinct vertices of G have distinct color codes, then c is called a *locating chromatic k -coloring* of G . The locating chromatic number, denoted by $\chi_L(G)$ is the smallest k such that G has a locating coloring with k colors.

The locating-chromatic number has been determined for some classes of graphs, namely cycles [1], multipartite graphs [1], and some classes of trees. Chartrand et al. [1] determined the locating chromatic number of path and double stars, then in [3] also

gave a characterization of all graphs of order n with locating-chromatic number $n - 1$. After this, Asmiati et al. [5] determined the locating-chromatic number an amalgamation of stars and non-homogeneous caterpillars and firecracker graphs in [4]. Behtoe and Omoomi [6] found the locating-chromatic number on the Kneser graph. Next, Baskoro and Purwasih [8] determined the locating-chromatic number for the corona product of graphs, then in [7] also gave a characterization of all graphs with locating-chromatic number 3. Recently, Ghanem et al. [9] found the locating chromatic number of powers of the path and powers of cycles.



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Based on the previous results, the locating chromatic number of modified path graphs have not been studied. Motivated by this, in this paper we determine the locating chromatic number of some modified path with cycle having locating number four.

Let us begin to state the following lemma and theorem which are useful to obtain our main result.

Lemma 1.1. Chartrand et al.[1] *Let c be a locating coloring in a connected graph G . If u and v are distinct vertices of G such that $d(u, w) = d(v, w)$ for all $w \in V(G) - \{u, v\}$ then $c(u) \neq c(v)$. In particular, if u and v are non-adjacent vertices of G such that $N(u) = N(v)$, then $c(u) \neq c(v)$.*

Theorem 1.1. Chartrand et al.[1] *For $n \geq 3$, the locating chromatic number of a path graph (P_n) is 3.*

2. Results and discussion

In this section, we will discuss the locating chromatic some modified path with locating chromatic number four.

Type 1 is a modified path obtained from a path P_n with v_i vertices $i = 1, \dots, n$ by adding vertex outside of P_n which will form C_3 , denoted by $P_n(C_3)$. The following is given the locating chromatic number of $P_n(C_3)$.

Theorem 2.1. The locating chromatic number of $P_n(C_3)$ is 4.

Proof: Let $P_n(C_3)$, $n \geq 3$, with the vertex set $V(P_n(C_3)) = \{u_i, v_i; 1 \leq i \leq n\}$ and the edge set $E(P_n(C_3)) = \{u_i v_i, u_i v_{i+1}; i \in [1, n - 1]\} \cup \{v_n v_{n+1}; i \in [1, n - 1]\}$.

First, we determine the lower bound for the modified graph of path for $n \geq 3$. According to Theorem 1.1, it is clear that $\chi_L P_n(C_3) \geq 3$. For a contradiction, suppose c is a locating coloring on $P_n(C_3)$ using 3 colors. Let $c(v_i) = \{1, 2, 3\} = c(u_i)$. Since u_i

adjacent to v_i and v_{i+1} , if $c(u_i) = \{c(v_j)\}$, then $c_\pi(u_i) = c_\pi(v_j), i \neq j$, a contradiction. As a result, needed at least 4 colors to color the modified graph of the path. So, $\chi_L P_n(C_3) \geq 4$.

Next, we determine the upper bound for the modified graph of the path for $n \geq 3$. Let c be a locating coloring using 4 colors as follows:

$$c(u_i) = 1, \text{ for } i \geq 1$$

$$2, \text{ for } i = 2n, n \geq 1$$

$$c(v_i) = \{3, \text{ for } i = 2n + 1, n \geq 1$$

$$14, \text{ for } i = 1$$

The color codes of $(P_n(C_3))$ are:

$$i, \text{ for } 4^{\text{th}} \text{ component, } i \geq 1$$

$$c_\pi$$

$$(u_i) =$$

$$0, \text{ for } 1^{\text{st}} \text{ component, } i \geq 1$$

$$2, \text{ for } 3^{\text{rd}} \text{ component, } i = 1$$

$$\{1, \text{ otherwise}$$

$$i - 1, \text{ for } 4^{\text{th}} \text{ component, } i \geq 1$$

$$0, \text{ for } 2^{\text{nd}} \text{ component, even } i, i \geq 2$$

$$c_\pi(v_i) =$$

$$2, \text{ for } 3^{\text{rd}} \text{ component, odd } i \geq 3$$

$$1, \text{ otherwise}$$

Since all vertices in $P_n(C_3)$ for $n \geq 3$ have distinct color codes, then c is a locating coloring using 4 colors. As a result $\chi_L P_n(C_3) \leq 4$. Thus, $P_n(C_3) = 4$. ■

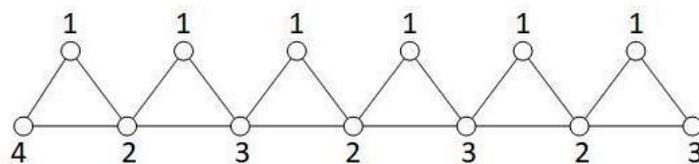


Figure. 1 The minimum locating coloring of $P_7(C_3)$.

Type 2 is obtained from $P_n(C_3)$ which insert one vertex x_i in $v_i v_{i+1}$, denoted by $P^*(C_n)$. The following theorem gives the locating chromatic number of $P^*(C)$. $n \geq 3$

Theorem 2.2. The locating chromatic number of $P^*(C)$ is 4. $n \geq 3$

Proof: Let $P^*(C)$, $n \geq 3$, with the vertex set $V(P^*(C)) = \{u_i, v_i; 1 \leq i \leq n\}$ and the edge set $E(P^*(C)) = \{u_i u_{i+1}, u_i v_i, v_i u_{i+1}; 1 \leq i \leq n-1\}$

$n \geq 3$

$$E(P^*(C)) = \{v_i; i \in [1, n-1]\} \cup \{u_i; i \in [1, n-1]\} \cup \{v_{2i+1}; i \in [1, n-1]\} \cup \{x_i; i \in [1, n-1]\} \cup \{v_{2i+1}; i \in [1, n-1]\}.$$

First, we determine the lower bound of $P^*(C)$. By Theorem 2.1, it is clear that $\chi(P^*(C)) \geq 4$.

$$L(P^*(C)) = 4$$

Next, we determine the upper bound. Let c be a locating coloring using 4 colors as follows:

$$c(u_i) = 1, \quad \text{for } i \geq 1$$

$$c(v_i) = \begin{cases} 3, & \text{for } i \geq 2 \\ 4, & \text{for } i = 1 \end{cases}$$

$$c(x_i) = 2, \quad \text{for } i \geq 1$$

The color codes of $(P^*(C))$ are:

$$c_{\pi}(u_i) = \begin{cases} i, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 1st component, } i \geq 1 \\ 2, & \text{for 2nd component, } i \geq 1 \\ \{1, \text{ otherwise} \end{cases}$$

$$c_{\pi}(v_i) = \begin{cases} 2(i-1), & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 3rd component, } i \geq 2 \\ 2, & \text{for 3rd component, } i = 1 \\ \{1, \text{ otherwise} \end{cases}$$

$$c_{\pi}(x_i) = \begin{cases} 2i-1, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 2nd component, } i \geq 2 \\ 2, & \text{for 1st component, } i \geq 1 \\ \{1, \text{ otherwise} \end{cases}$$

Since all vertices in $P^*(C)$ for $n \geq 3$ have distinct color codes, then c is locating coloring using $4n - 3$ colors. As a result, $\chi_L(P^*(C)) \leq 4n - 3$. Thus, $\chi(P^*(C)) = 4n - 3$. ■

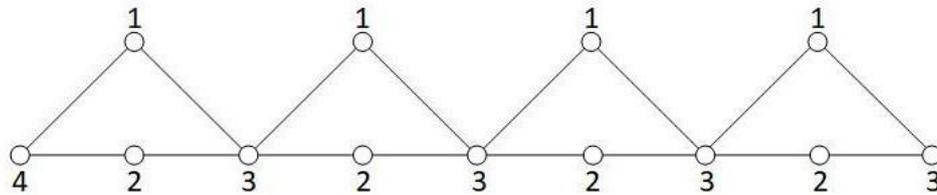


Figure 2. The minimum locating coloring of $P^*(C_3)$.

Type 3 is obtained from type 2 adding a vertex y_i outside of $P^*(C)$ such that $x_i y_i$ forms C , denoted by $sP^*(C)$. The following theorem gives the locating chromatic number of $sP^*(C)$.

$n - 3 \leq \chi(sP^*(C)) \leq n - 3$

Theorem 2.3. The locating chromatic number of $sP^*(C)$ is $n - 3$.

$n - 3$

Proof: Let $(sP^*(C))$, $n > 3$, with the vertex set $V(sP^*(C)) = \{u_i, v_i, x_i, y_i; 1 \leq i \leq n\}$ and the

$n - 3$

$n - 3$

$i - 1$

$i - 1$

edge set $E(sP^*(C)) = \{v_i u_i; i \in [1, n - 1]\} \cup \{x_i y_i; i \in [1, n - 1]\} \cup \{u_i v_{i+1}; i \in [1, n - 1]\} \cup \{u_n v_1\}$

$; i \in [1, n - 1] \cup n - 3$

$i - 1$

$i - 1$

$i - 1$

$\{y_i x_{i+1}; i \in [1, n - 1]\} \cup \{v_i x_i; i \in [1, n - 1]\} \cup \{x_i v_{i+1}; i \in [1, n - 1]\}$.

First, we determine the lower bound of $sP^*(C)$. By Theorem 2.2, We obtain $\chi(sP^*(C)) \geq n - 3$.

$n - 3 \leq \chi(sP^*(C)) \leq n - 3$

Next, we determine the upper bound of $sP^*(C)$. Let c be a locating coloring using $n - 3$ colors as follows:

$c(u_i) = 1, \quad \text{for } i \geq 1$

$n - 3$

$c(v_i) =$

$3, \quad \text{for } i \geq 2$

$\{$

$4, \quad \text{for } i = 1$

$c(x_i) = 2, \quad \text{for } i \geq 1$

$c(y_i) = 1, \quad \text{for } i \geq 1$

The color codes of $(sP^*(C))$ are:

$$n \geq 3$$

$$c_{\pi}$$

$$(u_i) =$$

$$\begin{cases} 2i - 1, & \text{for 4th component, } i \geq 2 \\ 0, & \text{for 1st component, } i \geq 1 \\ 2, & \text{for 2nd component, } i \geq 1 \\ 1, & \text{otherwise} \end{cases}$$

$$c_{\pi}$$

$$(v_i) =$$

$$\begin{cases} 2i - 2, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 3rd component, } i \geq 2 \\ 2, & \text{for 3rd component, } i = 1 \\ 1, & \text{otherwise} \end{cases}$$

$$c_{\pi}(x_i) = \{$$

$$\begin{cases} 2i - 1, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 2nd component, } i \geq 1 \\ 1, & \text{otherwise} \end{cases}$$

$$2i, \quad \text{for 4th component, } i \geq 1$$

$$c_{\pi}$$

$$(y_i) =$$

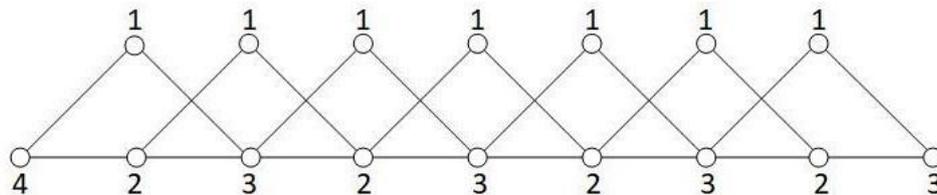
$$\begin{cases} 0, & \text{for 1st component, } i \geq 1 \\ 2, & \text{for 3rd component, } i \geq 1 \\ 1, & \text{otherwise} \end{cases}$$

Since all vertices in $P^*(C)$ for $n \geq 3$ have distinct color codes, then c is locating coloring.

So

$$n \geq 3$$

$$\chi_{L}(sP^*(C_3)) \leq 4. \text{ Thus, } \chi(sP^*(C_3)) = 4. \blacksquare$$



3. Conclusions

Figure 3. The minimum locating coloring of $sP^*(C_3)$.

In this research, we have successfully found modified path graph with cycle. Type 1 we

get by adding vertex outside of P_n which will form C_3 , denoted by $P_n(C_3)$. Type 2 is obtained from type 1 which insert one vertex x_i in $v_i v_{i+1}$, denoted by $P^*(C_n)$. Type 3 is obtained from type 2 adding a vertex y_i outside of $P^*(C)$ such that x y forms C , denoted by $sP^*(C)$. We Prove that the locating chromatic number of $P_n(C_3)$, $P^*(C_n)$ and $sP^*(C_3)$ are 4.

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THE LOCATING CHROMATIC NUMBER OF SOME MODIFIED PATH WITH CYCLE HAVING LOCATING NUMBER FOUR

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Abstract

The locating-chromatic number was introduced by Chartrand in 2002. The locating-chromatic number of a graph is a combined concept between the coloring and partition dimension of a graph. The locating chromatic number of a graph G is defined as the cardinality of minimum color classes. In this paper, we discuss about the locating chromatic number of three types modified path with cycle having locating chromatic number four.

Keyword: *locating chromatic number, path, cycle.*

1. Introduction

The locating-chromatic number of a graph is a combined concept between the coloring and partition dimension of graph. Chartrand et al. has been introduced the concept of the partition dimension of a graph in 1998 [2] and the concept of locating chromatic number of a graph in 2002 [1].

Let $G = (V, E)$ be a connected graph. Let c be a proper k -coloring of G with colors $1, 2, \dots, k$. Let $\pi = \{C_1, C_2, \dots, C_k\}$ be a partition of $V(G)$, where C_i is the set of vertices receiving color i . The color code $C_\pi(v)$ of v is the ordered k -tuple $(d(v, C_1), d(v, C_2), \dots, d(v, C_k))$ where $d(v, C_i) = \min\{d(v, x) | x \in C_i\}$ for any i . If all distinct vertices of G have distinct color codes, then c is called a *locating chromatic k -coloring* of G . The locating chromatic number, denoted by $\chi_L(G)$ is the smallest k such that G has a locating coloring with k colors.

The locating-chromatic number has been determined for some classes of graphs, namely cycles [1], multipartite graphs [1], and some classes of trees. Chartrand et al. [1] determined the locating chromatic number of path and double stars, then in [3] also gave a characterization of all graphs of order n with locating-chromatic number $n - 1$.

After this, Asmiati et al. [5] determined the locating-chromatic number an amalgamation of stars and non-homogeneous caterpillars and firecracker graphs in [4]. Behtoe and Omoomi [6] found the locating-chromatic number on the Kneser graph. Next, Baskoro and Purwasih [8] determined the locating-chromatic number for the corona product of graphs, then in [7] also gave a characterization of all graphs with locating-chromatic number 3. Recently, Ghanem et al. [9] found the locating chromatic number of powers of the path and powers of cycles.

Based on the previous results, the locating chromatic number of modified path graphs have not been studied. Motivated by this, in this paper we determine the locating chromatic number of some modified path with cycle having locating number four.

Let us begin to state the following lemma and theorem which are useful to obtain our main result.

Lemma 1.1. Chartrand et al.[1] *Let c be a locating coloring in a connected graph G . If u and v are distinct vertices of G such that $d(u, w) = d(v, w)$ for all $w \in V(G) - \{u, v\}$ then $c(u) \neq c(v)$. In particular, if u and v are non-adjacent vertices of G such that $N(u) = N(v)$, then $c(u) \neq c(v)$.*

Theorem 1.1. Chartrand et al.[1] *For $n \geq 3$, the locating chromatic number of a path graph (P_n) is 3.*

2. Results and discussion

In this section, we will discuss the locating chromatic some modified path with locating chromatic number four.

Type 1 is a modified path obtained from a path P_n with v_i vertices $i = 1, \dots, n$ by adding vertex outside of P_n which will form C_3 , denoted by $P_n(C_3)$. The following is given the locating chromatic number of $P_n(C_3)$.

Theorem 2.1. The locating chromatic number of $P_n(C_3)$ is 4.

Proof: Let $P_n(C_3)$, $n \geq 3$, with the vertex set $V(P_n(C_3)) = \{u_i, v_i; 1 \leq i \leq n\}$ and the edge set $E(P_n(C_3)) = \{u_i v_i, u_i v_{i+1}; i \in [1, n - 1]\} \cup \{v_n v_{n+1}; i \in [1, n - 1]\}$.

First, we determine the lower bound for the modified graph of path for $n \geq 3$. According to Theorem 1.1, it is clear that $\chi_L P_n(C_3) \geq 3$. For a contradiction, suppose c is a locating coloring on $P_n(C_3)$ using 3 colors. Let $c(v_i) = \{1, 2, 3\} = c(u_i)$. Since u_i adjacent to v_i and v_{i+1} , if $c(u_i) = \{c(v_j)\}$, then $c_\pi(u_i) = c_\pi(v_j)$, $i \neq j$, a contradiction. As a result, needed at least 4 colors to color the modified graph of the path. So, $\chi_L P_n(C_3) \geq 4$.

Next, we determine the upper bound for the modified graph of the path for $n \geq 3$. Let c be a locating coloring using 4 colors as follows:

$$c(u_i) = 1, \text{ for } i \geq 1$$

$$c(v_i) = \begin{cases} 2, & \text{for } i = 2n, n \geq 1 \\ 3, & \text{for } i = 2n + 1, n \geq 1 \\ 4, & \text{for } i = 1 \end{cases}$$

The color codes of $(P_n(C_3))$ are:

$$c_\pi(u_i) = \begin{cases} i, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 1st component, } i \geq 1 \\ 2, & \text{for 3rd component, } i = 1 \\ 1, & \text{otherwise} \end{cases}$$

$$c_\pi(v_i) = \begin{cases} i - 1, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 2nd component, even } i, i \geq 2 \\ & \text{for 3rd component, odd } i \geq 3 \\ 2, & \text{for 3rd component, } i = 1 \\ 1, & \text{otherwise} \end{cases}$$

Since all vertices in $P_n(C_3)$ for $n \geq 3$ have distinct color codes, then c is a locating coloring using 4 colors. As a result $\chi_L P_n(C_3) \leq 4$. Thus, $P_n(C_3) = 4$. ■

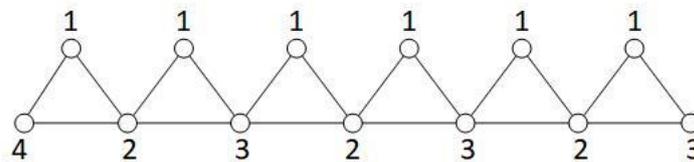


Figure. 1 The minimum locating coloring of $P_7(C_3)$.

Type 2 is obtained from $P_n(C_3)$ which insert one vertex x_i in $v_i v_{i+1}$, denoted by $P_n^*(C_n)$. The following theorem gives the locating chromatic number of $P_n^*(C_3)$.

Theorem 2.2. The locating chromatic number of $P_n^*(C_n)$ is 4.

Proof: Let $P_n^*(C_3)$, $n > 3$, with the vertex set $V(P_n^*(C_3)) = \{u_i, v_i; 1 \leq i \leq n\}$ and the edge set $E(P_n^*(C_3)) = \{v_{2i-1}u_i; i \in [1, n-1]\} \cup \{u_i v_{2i+1}; i \in [1, n-1]\} \cup \{v_i x_i; i \in [1, n-1]\} \cup \{x_i v_{i+1}; i \in [1, n-1]\}$.

First, we determine the lower bound of $P_n^*(C_3)$. By Theorem 2.1, it is clear that $\chi_L(P_n^*(C_3)) \geq 4$.

Next, we determine the upper bound. Let c be a locating coloring using 4 colors as follows:

$$c(u_i) = 1, \quad \text{for } i \geq 1$$

$$c(v_i) = \begin{cases} 3, & \text{for } i \geq 2 \\ 4, & \text{for } i = 1 \end{cases}$$

$$c(x_i) = 2, \quad \text{for } i \geq 1$$

The color codes of $(P_n^*(C_n))$ are:

$$c_\pi(u_i) = \begin{cases} i, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 1st component, } i \geq 1 \\ 2, & \text{for 2nd component, } i \geq 1 \\ 1, & \text{otherwise} \end{cases}$$

$$c_\pi(v_i) = \begin{cases} 2(i - 1), & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 3rd component, } i \geq 2 \\ 2, & \text{for 3rd component, } i = 1 \\ 1, & \text{otherwise} \end{cases}$$

$$c_{\pi}(x_i) = \begin{cases} 2i - 1, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 2nd component, } i \geq 1 \\ 2, & \text{for 1st component, } i \geq 1 \\ 1, & \text{otherwise} \end{cases}$$

Since all vertices in $P_n^*(C_3)$ for $n \geq 3$ have distinct color codes, then c is locating coloring using 4 colors. As a result, $\chi_L(P_n^*(C_3)) \leq 4$. Thus, $\chi_L(P_n^*(C_3)) = 4$. ■

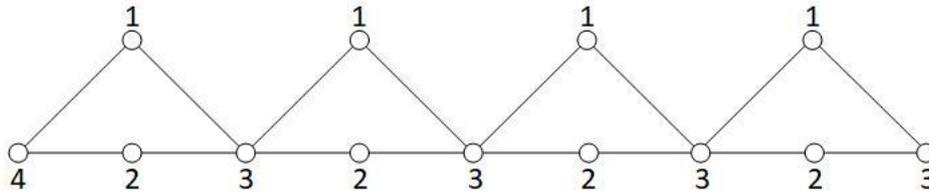


Figure 2. The minimum locating coloring of $P_5^*(C_3)$.

Type 3 is obtained from type 2 adding a vertex y_i outside of $P_n^*(C_3)$ such that $x_{i-1}y_i$ forms C_3 , denoted by $sP_n^*(C_3)$. The following theorem gives the locating chromatic number of $sP_n^*(C_3)$.

Theorem 2.3. The locating chromatic number of $sP_n^*(C_3)$ is 4.

Proof: Let $(sP_n^*(C_3))$, $n > 3$, with the vertex set $V(sP_n^*(C_3)) = \{u_i, v_i, x_i, y_i; 1 \leq i \leq n\}$ and the edge set $E(sP_n^*(C_3)) = \{v_i u_i; i \in [1, n - 1]\} \cup \{x_i y_i; i \in [1, n - 1]\} \cup \{u_i v_{i+1}; i \in [1, n - 1]\} \cup \{y_i x_{i+1}; i \in [1, n - 1]\} \cup \{v_i x_i; i \in [1, n - 1]\} \cup \{x_i v_{i+1}; i \in [1, n - 1]\}$.

First, we determine the lower bound of $sP_n^*(C_3)$. By Theorem 2.2, We obtain $\chi_L(sP_n^*(C_3)) \geq 4$.

Next, we determine the upper bound of $sP_n^*(C_3)$. Let c be a locating coloring using 4 colors as follows:

$$\begin{aligned} c(u_i) &= 1, & \text{for } i \geq 1 \\ c(v_i) &= \begin{cases} 3, & \text{for } i \geq 2 \\ 4, & \text{for } i = 1 \end{cases} \\ c(x_i) &= 2, & \text{for } i \geq 1 \\ c(y_i) &= 1, & \text{for } i \geq 1 \end{aligned}$$

The color codes of $(sP_n^*(C_3))$ are:

$$\begin{aligned} c_{\pi}(u_i) &= \begin{cases} 2i - 1, & \text{for 4th component, } i \geq 2 \\ 0, & \text{for 1st component, } i \geq 1 \\ 2, & \text{for 2nd component, } i \geq 1 \\ 1, & \text{otherwise} \end{cases} \\ c_{\pi}(v_i) &= \begin{cases} 2i - 2, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 3rd component, } i \geq 2 \\ 2, & \text{for 3rd component, } i = 1 \\ 1, & \text{otherwise} \end{cases} \\ c_{\pi}(x_i) &= \begin{cases} 2i - 1, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 2nd component, } i \geq 1 \\ 1, & \text{otherwise} \end{cases} \end{aligned}$$

$$c_{\pi}(y_i) = \begin{cases} 2i, & \text{for 4th component, } i \geq 1 \\ 0, & \text{for 1st component, } i \geq 1 \\ 2, & \text{for 3rd component, } i \geq 1 \\ 1, & \text{otherwise} \end{cases}$$

Since all vertices in $P_n^*(C_3)$ for $n \geq 3$ have distinct color codes, then c is locating coloring. So $\chi_L(sP_n^*(C_3)) \leq 4$. Thus, $\chi_L(sP_5^*(C_3)) = 4$. ■

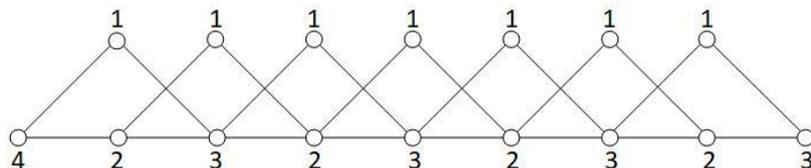


Figure 3. The minimum locating coloring of $sP_5^*(C_3)$.

3. Conclusions

In this research, we have successfully found modified path graph with cycle. Type 1 we get by adding vertex outside of P_n which will form C_3 , denoted by $P_n(C_3)$. Type 2 is obtained from type 1 which insert one vertex x_i in $v_i v_{i+1}$, denoted by $P_n^*(C_n)$. Type 3 is obtained from type 2 adding a vertex y_i outside of $P_n^*(C_3)$ such that $x_{i-1} y_i$ forms C_3 , denoted by $sP_n^*(C_3)$. We Prove that the locating chromatic number of $P_n(C_3)$, $P_n^*(C_n)$ and $sP_n^*(C_3)$ are 4.

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SUB-EXACT SEQUENCE OF ROUGH GROUPS

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Abstract

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Rough Set Theory (RST) is an essential mathematical tool to deal with imprecise, inconsistent, incomplete information and knowledge. Some algebra structures, such as groups, rings, and modules, have been presented on rough set theory. The sub-exact sequence is a generalization of the exact sequence. In this paper, we introduce the notion of a sub-exact sequence of groups. Furthermore, we give some properties of the rough group and rough sub-exact sequence of groups.

Key Words: exact sequence, sub-exact sequence, group; rough set.

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Introduction

Pawlak first introduced the rough set theory in 1982 (Pawlak, 1991). It is an advanced theory of set theory, in which the subsets of the universe are explained by a tuple of lower approximations and upper approximations. The basic concept of a rough set is the equivalence relation.

Let U is a finite non-empty set called universe set (power set), and θ is an equivalence relation in U . The tuple (U, θ) is called the approximation space (Miao et al., 2005). The lower approximation of a given set is a combination of all

equivalence classes that are the smallest subset. The upper approximation of a set X , denote by $Apr(X)$, combines all equivalence classes with the largest set. A tuple $(A,B) \in P(U) \times P(U)$ called rough set in (U, θ) , if $(A,B) = Apr(X)$, for $X \in P(U)$, where $P(U)$ is the power set of (U) and $Apr(X)$ is the approximation of X .

In 1994, Biswas and Nanda (Biswas & Nanda, 1994) introduced the rough subgroup. Furthermore, Kuroki (Kuroki, 1997) introduced the idea of rough ideals in semigroups in 1997. In 2001, Han Suqing (Han, 2001) investigated homomorphism and isomorphism on rough set. Subsequently, Davvaz (Davvaz, 2004) studied the relationship between the rough set and the ring theory by considering the ring as a universal set and introducing the abstraction ideal notation and the abstraction subring concerning the ideal of a ring. In 2006, Davvaz and Mahdavi-pour (Davvaz & Mahdavi-pour, 2006) investigated the rough module. After that, Sinha and Prakash (Sinha & Prakash, 2016) studied the exact sequence of the rough module. They define the exact sequence of rough modules on the rough ring $Apr(R)$.

Let R ring and let $A \xrightarrow{f} B \xrightarrow{g} C$ is the exact sequence over R -module such that $\text{im } f = \ker g (=g^{-1}(0))$. Davvaz and Parnian-Garamaleky (Davvaz & Parnian-Garamaleky, 1999) introduced the concept of U -exact by replacing 0 with submodule $U \subseteq C$. Motivated by Davvaz and Parnian-Garamaleky, which introduced the U -exact sequence concept, in 2016, Fitriani et al. (Fitriani et al., 2016) give new ideas from generalizing exact sequences to the X -sub-exact sequence of modules.

Let K, L, M be R -modules and X be a submodule of L . The triple (K, X, M) is said to be X -sub-exact on L if there is R -homomorphism of f and g so the sequence of R -modules dan R -homomorphisms $K \xrightarrow{f} X \xrightarrow{g} M$ is exact. They replace B with arbitrary submodule X of B . They denote all sub-module X in L so the sequence $A \xrightarrow{f} X \xrightarrow{g} C$ exact with $\sigma(A, X)$ and gives its properties.

Based on the definition of sub-exact sequence, in this paper we introduce the notion of a sub-exact sequence of rough groups. Furthermore, we give some properties of the rough group and sub-exact sequence of rough groups.

Research Methods

The research methods are based on the study of literature, especially those related to the standard set, the upper and lower approximations space, the rough group, the exact sequence, and the sub-exact sequence. Our research steps are as follows. First, we define the sub-exact sequences of rough groups. Furthermore, we investigate the properties of the rough group and the sub-exact sequences of groups, and also we construct the example of rough sub-exact sequence of groups by using the finite set.

The Results of the Research and the Discussion

Before we construct the rough sub-exact of groups, we recall the definition of rough group, sub-exact sequence, and exact sequence of the rough module over the rough ring as follows.

Definition 1. (Miao et al., 2005) Let $K = (U, R)$ be an approximation space and $*$ be a binary operation defined on U . A subset $G (G \neq \emptyset)$ of universe U is called a rough group if $Apr(G) = (\underline{Apr}(G), \overline{Apr}(G))$ the following properties are satisfied:

- (1) for every $x * y \in \overline{Apr}(G)$, $x * y \in G$;
- (2) association property holds in $\overline{Apr}(G)$;
- (3) there exists $e \in \overline{Apr}(G)$ such that $x \in G$, $x * e = e * x = x$; e is called the rough identity element of rough group G ;
- (4) for every $x \in G$, there exists $y \in G$, such that $x * y = y * x = e$; y is called the rough inverse element of x in G .

Definisi 2. (Fitriani et al., 2016) Let K, L, M be R -modules and X be a submodule of L . Then the triple (K, L, M) is said to be X -sub-eksak at L if there exist R -homomorphisms f and g such that the sequence of R -modules and R -homomorphisms $K \xrightarrow{f} X \xrightarrow{g} M$ is exact.

Definition 3. (Sinha & Prakash, 2016) A sequence $Apr(M') \xrightarrow{f} Apr(M) \xrightarrow{g} Apr(M'')$ of two homomorphism of a module over the ring $A(R)$ is said to be rough exact if $\text{im}(f) = \ker(g)$. This happens if and only if $gf = 0$, and the relation $g(x) = 0, x \in Apr(M)$, implies that $x = f(x')$ for some $x' \in Apr(M')$.

Based on the definition of sub-exact sequence of modules, we define the exact sequence of rough groups as follows.

Definition 4. Let A, B, C be rough groups, and X be a rough subgroup of B . Then the triple (A, B, C) is said to be rough X -sub-eksak at B if there exist homomorphisms f and g such that the sequence of groups and group homomorphisms $Apr(A) \xrightarrow{f} Apr(X) \xrightarrow{g} Apr(C)$ is exact.

Based on Definition 4, every rough exact sequence is a rough sub-exact sequence of groups. The converse need not be true. Before we give the properties of a rough sub-exact sequence, we provide the properties of the rough group as follows.

Proposition 5. Let (U, θ) be an approximation space, and let X_1, X_2 be subsets of U . If X_1 and X_2 are rough groups with $\overline{Apr}(X_1) = \overline{Apr}(X_2)$, then $X_1 \cup X_2$ is also the rough group.

Proof. Let $*$ be a binary operation defined on U . It is clear that $\overline{Apr}(X_1 \cup X_2) = \overline{Apr}(X_1) \cup \overline{Apr}(X_2)$.

By assumption, $\overline{Apr}(X_1) = \overline{Apr}(X_2)$. Let $a \in \overline{Apr}(X_1 \cup X_2)$ and $b \in \overline{Apr}(X_1 \cup X_2)$. Then $a \in \overline{Apr}(X_1)$ and $b \in \overline{Apr}(X_1)$. Since X_1 is the rough group, we have $a * b \in \overline{Apr}(X_1)$. Hence $a * b \in \overline{Apr}(X_1 \cup X_2)$.

For every $a, b, c \in X_1 \cup X_2$, associative property holds in $\overline{Apr}(X_1 \cup X_2)$, i.e. $a * (b * c) = (a * b) * c$.

Since X_1 is a rough group, we have the identity element $e \in \overline{Apr}(X_1) = \overline{Apr}(X_1 \cup X_2)$.

Finally, we want to show that every element in $\overline{Apr}(X_1 \cup X_2)$ has an inverse. By assumption, $\overline{Apr}(X_1) = \overline{Apr}(X_2)$, so that $\overline{Apr}(X_1 \cup X_2) = \overline{Apr}(X_1)$. This implies every element in the set $X_1 \cup X_2$ has an inverse in $\overline{Apr}(X_1 \cup X_2)$. Therefore, it proved $(X_1 \cup X_2)$ is a rough group.

By applying Proposition 3 to a finite number of subsets U , we have the following property of rough group.

Proposition 6. Let (U, θ) be an approximation space, and let X_1, X_2, \dots, X_n be subsets of U . If X_1, X_2, \dots, X_n are rough groups with $\overline{Apr}(X_1) = \overline{Apr}(X_2) = \dots = \overline{Apr}(X_n)$, then $\cup_{i=1}^n X_i$ is also the rough group.

Example 1. Let $U = \{0,1,2,3,4, \dots, 149\}$. We define the relation θ in U , where $u \theta v$ if and only if $u - v = 13k$, for some $k \in \mathbb{Z}$. It easy to show that θ is an equivalence relation on U . From this equivalence relation, we have 13 equivalence classes as follows:

$$\begin{aligned} E_1 &= [1] = \{1,14,27,40,53,66,79,92,105,118,131,144\}; \\ E_2 &= [2] = \{2,15,28,41,54,67,80,93,106,119,132,145\}; \\ E_3 &= [3] = \{3,16,29,42,55,68,81,94,107,120,133,146\}; \\ E_4 &= [4] = \{4,17,30,43,56,69,82,95,108,121,134,147\}; \\ E_5 &= [5] = \{5,18,31,44,57,70,83,96,109,122,135,148\}; \\ E_6 &= [6] = \{6,19,32,45,58,71,84,97,110,123,136,149\}; \\ E_7 &= [7] = \{7,20,33,46,59,72,85,98,111,124,137\}; \\ E_8 &= [8] = \{8,21,34,47,60,73,86,99,112,125,138\}; \\ E_9 &= [9] = \{9,22,35,48,61,74,87,100,113,126,139\}; \\ E_{10} &= [10] = \{10,23,36,49,62,75,88,101,114,127,140\}; \\ E_{11} &= [11] = \{11,24,37,50,63,76,89,102,115,128,141\}; \\ E_{12} &= [12] = \{12,25,38,51,64,77,90,103,116,129,142\}; \\ E_{13} &= [0] = \{0,13,26,39,52,65,78,91,104,117,130,143\}; \end{aligned}$$

The tuple (U, θ) is an approximate space.

Given the subsets $X = \{8,9,10,14,28,42,56,70,80,94,108,122,136,140,141,142\} \subseteq U$. Then the lower approximations of X is $\underline{Apr}(X) = \emptyset$, and the upper approximations of X is $\overline{Apr}(X) = E_1 \cup E_2 \cup E_3 \cup E_4 \cup E_5 \cup E_6 \cup E_7 \cup E_8 \cup E_9 \cup E_{10} \cup E_{11} \cup E_{12} \cup E_{13} = U$.

The rough set $Apr(X)$ is the ordered pair of the lower and upper approximations written as

$$Apr(X) = (\underline{Apr}(X), \overline{Apr}(X)) = (\{\}, \{0,1,2,3,4,5,6,7,8, \dots, 147,148,149,149\}).$$

We define the binary operation $+_{150}$ on rough set $Apr(X)$. We will show that X is a rough group.

- (1) For every $a, b \in X, (a +_{150} b) \in \overline{Apr}(X)$,
- (2) Association property holds in $\overline{Apr}(X)$;
- (3) There exists $0 \in \overline{Apr}(X)$ such that for every $x \in X, x +_{150} 0 = 0 +_{150} x = x$.
- (4) The following table shows that every element in X has inverse in $\overline{Apr}(X)$.

$x \in X$	8	9	10	14	28	42	56	70
x^{-1}	142	141	140	136	122	108	94	80

Table 1. Inverse element on X

Based on Table 1, we have every element of X has an inverse in $\overline{Apr}(X)$. Hence X is a rough group on U .

If we take $X_1 = \{8,9,10,14,28,31,42,56,70,80,94,108,119,122,136,140,141, 142\}$, and $X_2 = \{8,9,10,14,28,42,44,56,70,80,94,106,108,122, 136,140,141,142\}$. We can show that X_1 dan X_2 are rough groups. Next, we will show that $X_1 \cup X_2$ is a rough group in approximation space (U, θ) .

We have $X_1 \cup X_2 = \{8,9,10,14,28,31,42,44,56,70,80,94,106,108,119,122, 136,140, 141,142\}$. This implies $\overline{Apr}(X_1 \cup X_2) = U$. If we take $+_{150}$ as a binary operation in U , we get $(a +_{150} b) \in \overline{Apr}(X_1 \cup X_2)$, for every $a, b \in X_1 \cup X_2$.

Futhermore, associative property holds in $\overline{Apr}(X_1 \cup X_2)$. It has an $e \in \overline{Apr}(X_1 \cup X_2)$ identity element, i.e. $0 \in \overline{Apr}(X_1 \cup X_2)$ so that for each $x \in X_1 \cup X_2, x +_{150} 0 = 0 +_{150} x = x$. Then 0 elements of identity in $X_1 \cup X_2$.

Every element in the $X_1 \cup X_2$ has an inverse in $\overline{Apr}(X_1 \cup X_2) = U$. So, the set $(X_1 \cup X_2)$ is a rough group in approximation space (U, θ) . This is shown that the union of two rough groups which the same upper approximation is also a rough group.

Next, we will give the properties of sub-exact sequence of rough groups.

Proposition 7. Let (U, θ) be an approximation space, and let X_1, X_2 be rough groups of U , such that $\overline{Apr}(X_1) = \overline{Apr}(X_2)$. The triple (U', U, U'') is an X_1 -sub-exact sequence if and only if the triple (U', U, U'') is an X_2 -sub-exact sequence.

Proof. It is clear from Definition 4.

Conclusion and Suggestion

The sub-exact sequence of rough groups is a generalization of exact sequence of rough groups. The union of finite rough groups which the same upper approximation is also a rough group. Let (U, θ) be an approximation space, and let X_1, X_2 be rough groups of U , such that $\overline{Apr}(X_1) = \overline{Apr}(X_2)$. The triple (U', U, U'') is an X_1 -sub-exact sequence if and only if the triple (U', U, U'') is an X_2 -sub-exact sequence.

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PENGARUH PEMBERIAN EKSTRAK ETANOL JAHE MERAH (ZINGIBER OFFICINALE ROXB. VAR. RUBRUM) DAN ZINC (ZN) TERHADAP KADAR TESTOSTERON INTRATESTIKULAR, KUANTITAS DAN KUALITAS SPERMATOSOA MENCIT (MUS MUSCULUS L.) YANG DIINDUKSI HORMON PROGESTERON

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ABSTRACT

Infertility is a problem that often occurs, it is estimated that around 10-15% of married couples. The factor of infertility from the husband is caused by damage to spermatozoa function. Spermatogenesis runs perfectly because of the presence of testosterone, so there is a relationship between intratesticular testosterone levels and spermatozoa production. Spermatogenesis also requires an important mineral, zinc. One of the plants as anti-infertility is red ginger. The effect of giving red ginger can also increase the hormone testosterone. It also significantly affects the increase in sperm percentage, viability, motility and also the total serum testosterone. The purpose of this study was to determine the effect of giving red ginger extract and zinc to intratesticular testosterone levels, quantity and quality of progesterone-induced mouse spermatozoa. This study used a Completely Randomized Design (CRD) with four treatment groups and was repeated five times. Group P1 (control / aquades), P2 (DMPA 1.25mg / kg BW and distilled water), P3 (DMPA 1.25mg / kg BW and red ginger extract 400 mg / kg and Zn 1 mg / kg BW), P4 (DMPA 1.25mg / kg BW and red ginger extract 600 mg / kg BW and Zn 1 mg / kg BW). Data were analyzed by One Way ANOVA and the least significant difference test (LSD) at the 5% real level. The results showed that changes in the value of intratesticular testosterone levels from 8.06 ng / ml to 13.44 ng / ml and 26.06 ng / ml, the value of spermatozoa concentration from 12.92 x10⁶ cells / ml to 16.52 x10⁶ cells / ml and 24.48 x10⁶ cells / ml, the percentage of spermatozoa motility from 13.63% to 22.18% and 63.84%, the percentage of spermatozoa morphology from 33.58% to 37.44% and 59.4%, the percentage of spermatozoa viability from 23.88% to 31.35% and 65.24%.

It was concluded that giving red ginger and zinc ethanol extract can increase intratesticular testosterone levels, spermatozoa quantity (spermatozoa concentration) and spermatozoa quality (motility, morphology, and viability of spermatozoa).

Keywords: intratesticular testosterone, spermatozoa quantity and quality, red ginger, progesterone hormone.

PENDAHULUAN

Infertilitas merupakan suatu masalah yang sering terjadi, diperkirakan sekitar 10-15% pasangan suami istri. Sekitar 11-15% pasangan suami istri sulit memiliki keturunan disebabkan oleh faktor infertilitas dari suami. Hal tersebut sesuai dengan penelitian dari WHO (*World Health Organization*) (Triwani, 2013).

Kasus umum infertilitas pada pria salah satunya disebabkan oleh kerusakan fungsi spermatozoa. Kualitas dan kuantitas spermatozoa tergantung dari spermatogenesis yang terjadi di testis. Testis tersusun atas tubulus seminiferus, tempat berlangsungnya proses spermatogenesis. Di dalam testis terdapat sel Leydig yang berfungsi menghasilkan testosteron. Testosteron merupakan steroid intratestikular yang dominan di dalam testis. Testosteron sangat penting untuk proses pembentukan spermatozoa (Jarow *et al*, 2005). Zinc (Zn) merupakan suatu mineral penting untuk kebutuhan reproduksi laki-laki termasuk metabolisme testosteron, pembentukan spermatozoa, dan motilitas spermatozoa (Ali *et al*, 2007).

Jahe merupakan salah satu tanaman yang dicari masyarakat karena memiliki manfaat terutama bagi kesehatan. Pemanfaatan tanaman obat seperti jahe sudah lama digunakan untuk menyembuhkan maupun mencegah penyakit. Khususnya jahe merah memberikan efek meningkatkan hormon testosteron, LH (*Luteinizing Hormone*) dan melindungi testis dari efek radikal bebas. Jahe merah juga mempunyai pengaruh terhadap spermatogenesis. Secara signifikan juga berpengaruh terhadap peningkatan presentasi spermatozoa, viabilitas, motilitas dan juga total serum testosteron (Khaki *et al.*, 2009).

Pemberian ekstrak jahe merah dan zinc berpengaruh terhadap jumlah spermatozoa tikus putih (Rahmanisa dan Maisuri, 2013). Pemberian ekstrak air jahe merah dan dikombinasikan dengan zinc terhadap tikus secara efektif meningkatkan fungsi steroidogenesis dan spermatogenesis pada tikus dan dengan demikian penambahan zinc dapat digunakan sebagai herbal kesuburan potensial pada pria (Sutyarso *et al*, 2016).

Untuk itu perlu dilakukan penelitian tentang pengaruh pemberian ekstrak jahe merah dan zinc terhadap kadar testosteron intratestikular, kuantitas dan kualitas spermatozoa pada mencit yang diinduksi hormon progesteron.

METODE PENELITIAN

Alat dan bahan

Penelitian ini merupakan penelitian eksperimental. Bahan penelitian ini adalah 20 ekor mencit jantan usia 2-3 bulan dengan berat badan 30gr, jahe merah, zinc, awuades,

eosin, NaCl, giemsa, methanol, DMPA (*Dempo Medroxy Progesterone Acetat*) menjadikan mencit dengan keadaan infertil, dan Kit ELISA. Alat yang dipakai adalah kandang mencit, alat suntik, sonde lambung, sentrifuge, mikropipet, tube, timbangan, batang pengaduk, incubator, dan Elisa Reader.

Penentuan Dosis Hormon Progesteron

Hormon progesteron yang digunakan jenis DMPA (*Dempo Medroxy Progesterone Acetate*) yang memiliki dosis 150 mg/3ml. Hormon tersebut diberikan ke mencit untuk menjadikan mencit menjadi infertil. Menurut Suryandari dan Moeloek (2009) berbagai dosis DMPA yaitu 1,25 mg, 0,62 mg, 0,31 mg didapatkan dosis minimal DMPA yang dapat menurunkan konsentrasi dan viabilitas spermatozoa, serta kadar hormon testosteron pada tikus adalah dosis 1, 25 mg.

Penentuan Dosis Jahe Merah

Menurut Tanuwireja (2007) penentuan dosis jahe merah yang efektif untuk mencit yaitu 400 mg/kgBB. Pada penelitian ini menggunakan dosis yang efektif yaitu 400 mg/KgBB dan setengah kali lipat dari dosis efektif yaitu 600 mg/KgBB untuk mengetahui dosis yang lebih efektif.

Penyediaan Zinc (Zn)

Berdasarkan penelitian yang dilakukan oleh Rahmanisa dan Maisuri (2013) pemberian ekstrak jahe merah dan zinc 1 mg/KgBB berpengaruh terhadap jumlah spermatozoa pada tikus putih jantan dewasa.

Hewan Uji dan Rancangan Penelitian

Penelitian telah dilaksanakan pada bulan Agustus sampai Oktober 2020 yang menggunakan Rancangan Acak Lengkap (RAL) dengan empat kelompok perlakuan dan diulang lima kali. Kelompok P1 (kontrol/ aquades), P2 (DMPA 1,25mg/kg BB dan aquades), P3 (DMPA 1,25mg/kg BB dan ekstrak jahe merah 400 mg/kgBB serta Zn 1 mg/kg BB), P4 (DMPA 1,25mg/kg BB dan ekstrak jahe merah 600 mg/kg BB serta Zn 1 mg/kg BB). Pemberian ekstrak etanol jahe merah dan zinc selama 33 hari secara oral. Pemberian DMPA selama satu kali dalam seminggu selama dua minggu.

Uji Kadar Testosteron Intratestikular

Sampel testis ditimbang kemudian diberikan larutan PBS (*Phosphate Buffer Saline Solution*) sebanyak 1gr : 1 ml. Sampel testis dihancurkan secara manual kemudian di hancurkan kembali menggunakan ultrasonic. Sampel disentrifus dengan speed 6688 rpm RCF 5000 Xg selama 15 menit pada suhu 10⁰C. Supernatan diambil dan disimpan dalam eppendrof pada suhu -80⁰C sampai dilakukan pengukuran. Pengukuran dilakukan dengan mencairkan sampel yang telah membeku. Setelah cair dilakukan pengukuran kadar testosteron intratestikular menggunakan ELISA reader.

Langkah pertama yaitu menyiapkan 27 well yang akan diisi dengan sampel. Siapkan well yang kosong tidak berisi apapun sebanyak satu lubang, enam well

ditambahkan 50 µl larutan standar dengan konsentrasi 0 ng/ml, 0,1 ng/ml, 0,4 ng/ml, 1,6 ng/ml, 5 ng/ml, dan 20 ng/ml, 20 well selanjutnya diisi oleh sampel supernatant sebanyak 50µl. Semua well ditambahkan 50µl HRP-konjugasi kecuali well yang kosong. Ditambahkan antibodi kesemua well. Diinkubasi selama 1 jam pada suhu 37⁰ C.

Semua well dicuci menggunakan wash buffer yang telah diencerkan (5 ml : 100 ml aquades) sebanyak 3 kali (setiap pencucian di diamkan selama 10 detik). Ditambahkan 50 µl substrat A dan 50 µl substrat B ke semua well. Diinkubasi selama 15 menit dengan suhu yang sama. Ditambahkan 50 µl larutan stop solution ke semua well. Tahap terakhir well ditempatkan di ELISA reader maka data akan terbaca di komputer.

Uji Kuantitas Spermatozoa

Jumlah Spermatozoa

Jumlah spermatozoa dihitung dengan menggunakan bilik hitung *improved Neubauer* (hemositometer). Suspensi spermatozoa yang telah diencerkan dengan 1 mL larutan garam fisiologis (NaCl 0,9%) diambil 10 µL kemudian diletakkan ke dalam bilik hitung (hemositometer), setelah itu ditutup dengan gelas penutup. Diamati di bawah mikroskop cahaya dengan perbesaran 20x10.

Jumlah spermatozoa dihitung dengan rumus :

$$\text{jumlah sel/mL} = \text{jumlah spermatozoa (dalam 5 kotak)} \times 10^6$$

Uji Kualitas Spermatozoa

Motilitas Spermatozoa

Pemeriksaan motilitas spermatozoa dilakukan menggunakan mikroskop perbesaran 20x10, motilitas spermatozoa dikelompokkan ke dalam kategori sel spermatozoa (A) bergerak dan (B) tidak bergerak (Astuti,2009). Persentase motilitas dihitung berdasarkan rumus perhitungan sebagai berikut:

$$\frac{A}{A+B} \times 100\%$$

Morfologi Spermatozoa

Satu tetes suspensi spermatozoa diteteskan pada kaca objek, dibuat sediaan oles dengan menggeserkan kaca objek lain di atasnya, dikering anginkan, difiksasi dengan metanol 70% selama 5 menit dan diwarnai dengan larutan giemsa selama 30 menit dan dibilas dengan air mengalir. Penghitungan dilakukan di bawah mikroskop dengan pembesaran 40x10. A(spermatozoa abnormal), B(Spermatozoa Normal) (Astuti,2009). Persentase morfologi spermatozoa:

$$\frac{A}{A+B} \times 100\%$$

Viabilitas Spermatozoa

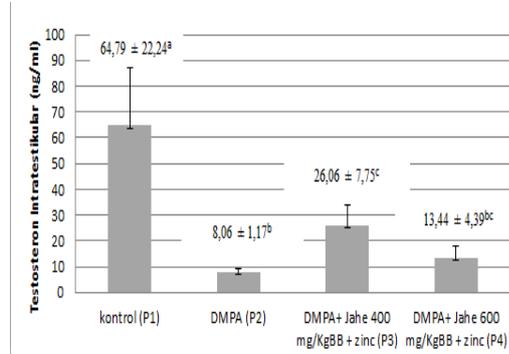
satu tetes suspense spermatozoa, diteteskan pada gelas objek dan dicampurkan larutan eosin negrosin. Kemudian ditutup menggunakan cover glass. Viabilitas spermatozoa dihitung menggunakan mikroskop cahaya dengan perbesaran 40x10. A(spermatozoa jernih) B(spermatozoa berwarna) (Astuti,2009).

$$\frac{A}{A+B} \times 100\%$$

HASIL

Hasil Pengamatan Kadar Testosteron Intratestikular

Hasil pengamatan pengaruh pemberian ekstrak etanol jahe merah dan zinc terhadap kadar testosteron intratestikular mencit yang telah diinduksi hormon progesteron dapat dilihat pada Gambar 1.



Angka yang diikuti huruf berbeda menunjukkan beda nyata berdasarkan uji BNT 5%

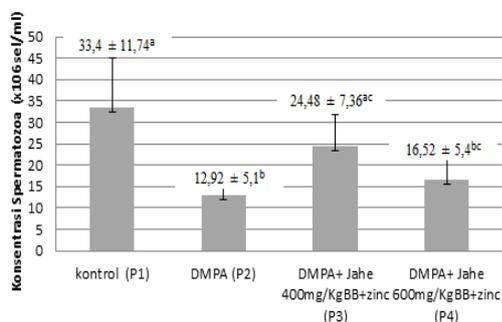
Gambar 1. Kadar Testosteron Intratestikular (ng/ml) Mencit yang Diinduksi Hormon Progesteron dan Diberikan Ekstrak Jahe Merah serta zinc.

Hasil uji *one way Anova (Analysis of Variance)* terhadap kadar testosteron intratestikular pada setiap kelompok perlakuan menunjukkan adanya pengaruh yang bermakna ($p < 0,05$). Hasil analisis statistik menunjukkan adanya pengaruh pemberian ekstrak etanol jahe merah dan zinc terhadap kadar testosteron intratestikular pada mencit yang diinduksi hormon progesteron.

Hasil Pengamatan Kuantitas Spermatozoa

Hasil Pengamatan Konsentrasi Spermatozoa

Pengaruh pemberian ekstrak etanol jahe merah dan zinc terhadap konsentrasi spermatozoa mencit yang telah diinduksi hormon progesteron dapat dilihat pada Gambar 2.



Angka yang diikuti huruf berbeda menunjukkan beda nyata berdasarkan uji BNT 5%

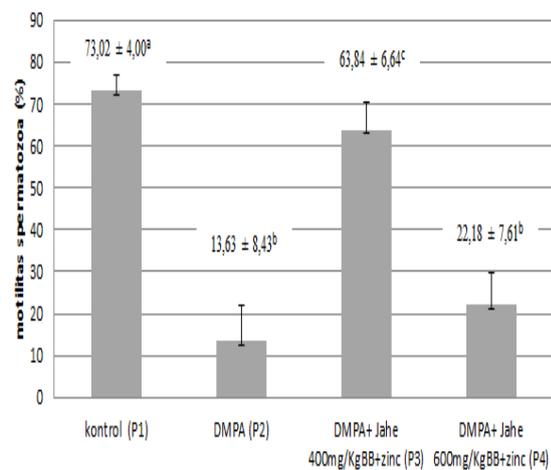
Gambar 8. Konsentrasi Spermatozoa ($\times 10^6$ sel/ml) Mencit yang Diinduksi Hormon Progesteron dan Diberikan Ekstrak Jahe Merah serta zinc.

Hasil uji *one way Anova (Analysis of Variance)* terhadap nilai konsentrasi spermatozoa pada setiap kelompok perlakuan menunjukkan adanya pengaruh yang bermakna ($p < 0,05$). Hasil analisis statistik menunjukkan adanya pengaruh pemberian ekstrak etanol jahe merah dan zinc terhadap nilai konsentrasi spermatozoa pada mencit yang diinduksi hormon progesteron.

Hasil Pengamatan Kualitas Spermatozoa

Hasil Pengamatan Motilitas Spermatozoa

Pengaruh pemberian ekstrak etanol jahe merah dan zinc terhadap motilitas spermatozoa mencit yang telah diinduksi hormon progesteron dapat dilihat pada Gambar 3.



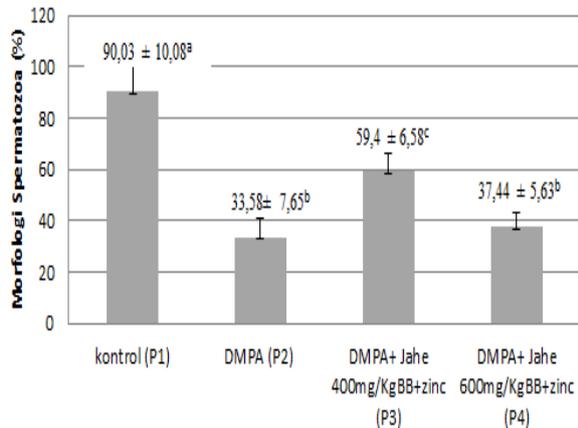
Angka yang diikuti huruf berbeda menunjukkan beda nyata berdasarkan uji BNT 5%

Gambar 3. Persentase Motilitas Spermatozoa (%) Mencit yang Diinduksi Hormon Progesteron dan Diberikan Ekstrak Jahe Merah Serta Zinc.

Hasil uji *one way Anova (Analysis of Variance)* terhadap nilai motilitas spermatozoa pada setiap kelompok perlakuan menunjukkan adanya pengaruh yang bermakna ($p < 0,05$). Hasil analisis statistik menunjukkan adanya pengaruh pemberian ekstrak etanol jahe merah dan zinc terhadap nilai motilitas spermatozoa pada mencit yang diinduksi hormon progesteron.

Hasil Pengamatan Morfologi Spermatozoa

Pengaruh pemberian ekstrak etanol jahe merah dan zinc terhadap morfologi spermatozoa mencit yang telah diinduksi hormon progesteron dapat dilihat pada Gambar 4.



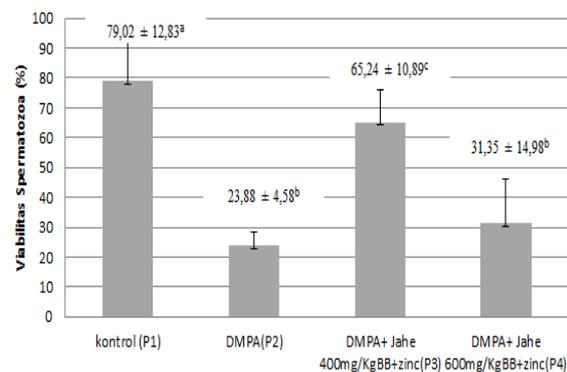
Angka yang diikuti huruf berbeda menunjukkan beda nyata berdasarkan uji BNT 5%

Gambar 4. Persentase Morfologi Spermatozoa (%) Mencit yang Diinduksi Hormon Progesteron dan Diberikan Ekstrak Jahe Merah Serta Zinc.

Hasil uji *one way Anova (Analysis of Variance)* terhadap nilai morfologi spermatozoa pada setiap kelompok perlakuan menunjukkan adanya pengaruh yang bermakna ($p < 0,05$). Hasil analisis statistik menunjukkan adanya pengaruh pemberian ekstrak etanol jahe merah dan zinc terhadap nilai morfologi spermatozoa pada mencit yang diinduksi hormon progesteron.

Hasil Pengamatan Viabilitas Spermatozoa

Pengaruh pemberian ekstrak etanol jahe merah dan zinc terhadap viabilitas spermatozoa mencit yang telah diinduksi hormon progesteron dapat dilihat pada Gambar 5.



Angka yang diikuti huruf berbeda menunjukkan beda nyata berdasarkan uji BNT 5%

Gambar 12. Persentase Viabilitas Spermatozoa (%) Mencit yang Diinduksi Hormon Progesteron dan Diberikan Ekstrak Jahe Merah Serta Zinc.

Hasil uji *one way Anova (Analysis Of Variance)* terhadap nilai viabilitas spermatozoa pada setiap kelompok perlakuan menunjukkan adanya pengaruh yang bermakna ($p < 0,05$).

Hasil analisis statistik menunjukkan adanya pengaruh pemberian ekstrak etanol jahe merah dan zinc terhadap nilai viabilitas spermatozoa pada mencit yang diinduksi hormon progesteron.

Pembahasan

Penelitian ini hormon progesteron yang digunakan yaitu DMPA (*Dempo Medroxy Progesterone Acetate*). Dimana DMPA merupakan kontrasepsi suntik yang mengandung progestin yang biasanya digunakan untuk kontrasepsi wanita. Mekanisme utama dari DMPA yaitu menghambat *Gonadotropin Releasing Hormon* (GnRH) sehingga sekresi *Folicle Stimulating Hormon* (FSH) dan *Luteinizing Hormone* (LH) juga akan terhambat. *Luteinizing Hormone* berfungsi untuk menstimulasi sel Leydig untuk menghasilkan testosterone, sedangkan fungsi dari FSH yaitu mempengaruhi sel Sertoli untuk pembentukan *Androgen Binding Protein* (ABP). *Androgen Binding Protein* berfungsi untuk mengikat testosterone intratesticular yang dihasilkan oleh sel Leydig. Dengan terhambatnya FSH dan LH spermatogenesis akan terhambat dan terganggu untuk menghasilkan spermatozoa (Foa, et al. 2006).

Pada Gambar 7 menunjukkan adanya peningkatan kadar testosterone intratestikular mencit setelah diberikan ekstrak jahe merah dengan dosis berurutan 400 mg/KgBB dan 600 mg/KgBB yang masing-masing ditambahkan dengan zinc 1 mg/KgBB. Dengan adanya peningkatan tersebut diduga ekstrak jahe merah yang ditambahkan dengan zinc dapat meningkatkan kadar testosterone intratestikular. Hal tersebut sesuai dengan penelitian Khaki et al (2009) yang menyatakan bahwa pemberian jahe merah dapat meningkatkan hormon testosterone tikus putih serta jahe merah juga meningkatkan testosterone dalam serum. Penelitian Sutyarso et al (2016) menyatakan bahwa pemberian jahe yang dikombinasi dengan zinc dapat meningkatkan testosterone, selain itu penambahan zinc juga diduga dapat meningkatkan kadar testosterone intratestikular. Zinc ditemukan terutama di sel Leydig, Spermatogonia tipe B dan spermatid di mana zinc ini dapat membantu mensekresikan testosterone dari sel Leydig.

Peningkatan konsentrasi spermatozoa setelah diberikan ekstrak jahe merah yang ditambahkan dengan zinc diduga pada fakta peningkatan testosterone intratestikular yang memacu peningkatan konsentrasi spermatozoa. Hal tersebut sesuai dengan penelitian Sutyarso et al (2016) menunjukkan bahwa kombinasi dari jahe merah dan zinc meningkatkan spermatogenesis yang mengacu pada konsentrasi spermatozoa pada tikus. Peningkatan konsentrasi spermatozoa disebabkan efek jahe merah dan zinc yang dapat menghambat apoptosis.

Peningkatan konsentrasi spermatozoa disebabkan karena senyawa fenolik yang terkandung dalam jahe merah yang berfungsi sebagai mencegah kerusakan dari sel Sertoli dan sel leydig dan spermatogenesis kembali normal sehingga konsentrasi spermatozoa yang dihasilkan meningkat (Septiana, 2002). Jahe merah juga dapat meningkatkan hormon testosterone yang berperan dalam spermatogenesis sehingga dapat meningkatkan kualitas spermatozoa termasuk peningkatan konsentrasi spermatozoa (Kamtchouing, et al, 2002).

Penambahan zinc di dalam ekstrak juga diduga dapat meningkatkan motilitas spermatozoa. Hal tersebut sesuai dengan penelitian Payaran *et al* (2014) yang menyatakan bahwa pemberian zinc dapat meningkatkan motilitas spermatozoa. Karena fungsi dari mineral zinc yang bekerja terhadap kerja enzim metabolisme sel yang dapat menyediakan ATP sebagai energi gerak bagi spermatozoa yang menyebabkan spermatozoa bergerak aktif. Motilitas terbentuk di epididimis. Motilitas spermatozoa tidak berhubungan dengan testosteron intratestikular tetapi berhubungan dengan DHT (*Dehidrotestpsteron*). *Dehidrotestpsteron* merupakan androgen yang dibutuhkan di epididimis untuk pematangan spermatozoa. DHT berasal dari perubahan dari testosteron oleh enzim 5α -reduktase. Pada hasil penelitian ini motilitas spermatozoa mencit jantan meningkat setelah pemberian jahe. Hal tersebut diduga aktivitas enzim 5α -reduktase meningkat setelah pemberian jahe merah, sehingga kadar DHT di dalam epididimis terpenuhi dalam meningkatkan fungsi epididimis.

Senyawa jahe merah dapat memacu aktivitas androgenik (baik LH maupun FSH) untuk organ testis sehingga spermatogenesis yang terjadi di epididimis akan terjadi secara sempurna sehingga kualitas spermatozoa meningkat termasuk menurunnya keabnormalitas spermatozoa (Ali, *et al.*, 2008). Selain itu, penambahan zinc di dalam ekstrak diduga dapat meningkatkan kenormalan spermatozoa karena zinc dapat menstimulasi hormone androgen sehingga dapat meningkatkan spermatogenesis yang normal dan pematangan spermatozoa.

Menurut Widiowati *et al* (2008) menyatakan bahwa mineral yang terkandung di dalam zinc menyebabkan peningkatan pada sel spermatogenik karena adanya peningkatan testosteron. Testosteron dari tubulus seminiferus diikat oleh ABP dan ditranportasikan menuju ke epididimis. Selama di epididimis testosteron diubah oleh enzim 5α reduktase menjadi DHT yang berfungsi menghilangkan sisa-sisa sitoplasma yang menempel di spermatozoa setelah keluar dari tubulus seminiferus. Meningkatnya DHT menyebabkan mekanisme penghilang sisa sitoplasma menjadi lebih efektif, sehingga menimbulkan perbaikan pada morfologi normal spermatozoa.

Kesempurnaan fungsi epididimis tergantung pada kadar testosteron. Apabila testosteron yang dihasilkan sedikit maka fungsi dari epididimis terganggu karena nutrisi yang diperlukan tidak tersedia dalam jumlah yang cukup sehingga proses pematangan spermatozoa akan terganggu dan menurunnya viabilitas spermatozoa (Herrero, *et al.*, 2001).

Dari hasil penelitian ini bahwa pemberian ekstrak jahe merah 400 mg/KgBB yang ditambahkan dengan zinc 1 mg/KgBB memberikan efek perubahan yang lebih tinggi di bandingkan dengan pemberian ekstrak jahe merah dosis 600 mg/KgBB yang ditambahkan dengan zinc 1 mg/KgBB. Karena penggunaan dosis yang berlebihan dapat menimbulkan kerusakan pada spermatogenesis.

Jahe memiliki kandungan senyawa kimia salah satunya arginin. Jika kadar arginin yang masuk ke dalam tubuh dengan dosis yang berlebih maka akan menyebabkan efek proteksi terhadap membran aksonema menghilang.

Sifat jahe merah bukan hanya sebagai imunomodulator, vasodilator atau neurotransmitter, tetapi juga sebagai antioksidan. Jika di dalam tubuh kadarnya

berlebihan sudah tidak dapat ditoleransi dan fungsinya menjadi berbahaya bagi sel-sel di dalam tubuh. Inilah yang menyebabkan perbedaan lebih rendah kadar testosteron intratestikular, kuantitas spermatozoa berupa konsentrasi spermatozoa, kualitas spermatozoa berupa motilitas, morfologi dan viabilitas spermatozoa mencit jantan pada pemberian dosis 600 mg/KgBB dibandingkan dengan dosis 400 mg/KgBB (Srivastava et al., 2006).

KESIMPULAN

Adapun kesimpulan yang didapat dari penelitian ini adalah pemberian ekstrak jahe merah dan zinc pada mencit yang diinduksi hormon progesteron dapat:

1. Meningkatkan kadar testosteron intratestikular
2. Meningkatkan kuantitas spermatozoa berupa meningkatnya konsentrasi spermatozoa.
3. Meningkatkan kualitas spermatozoa berupa meningkatnya motilitas, morfologi, viabilitas spermatozoa.

SARAN

Adapun saran dari penelitian ini adalah:

1. Perlu dilakukan penelitian lebih lanjut mengenai kadar FSH dan LH pada mencit jantan dengan perlakuan yang sama .
2. Perlu dilakukan penelitian lebih lanjut mengenai Imunohistokimia (IHK) pada testis mencit jantan.

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EFEK PENAMBAHAN POWDER *Nannochloropsis* sp. DENGAN DOSIS YANG BERBEDA PADA PAKAN KOMERSIL TERHADAP PERFORMA PERTUMBUHAN DAN KETAHANAN TUBUH IKAN KAKAP PUTIH (*Lates calcarifer*, Bloch 1790) TERHADAP BAKTERI PATOGEN

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ABSTRAK

Ikan kakap putih (*Lates calcarifer*, Bloch 1790) adalah salah satu ikan ekonomis penting di kawasan Asia dan Australia. Kendala yang sering menghambat budidaya ikan ini adalah seringnya terinfeksi bakteri patogen *Vibrio alginolyticus* dan pertumbuhan yang lambat. Untuk menanggulangi serangan bakteri patogen dapat digunakan bahan sumber daya hayati yaitu *Nannochloropsis* sp. Penelitian ini bertujuan untuk mengetahui efektifitas powder *Nannochloropsis* sp. terhadap performa pertumbuhan dan ketahanan tubuh ikan kakap putih (*Lates calcarifer*, Bloch 1790).

Penelitian ini dilaksanakan pada bulan September- sampai November 2019 di Balai Besar Perikanan Budidaya Laut Lampung (BBPBL) Desa Hanura Kecamatan Teluk Pandan Kabupaten Pesawaran Provinsi Lampung. Metode penelitian menggunakan rancangan acak lengkap (RAL) dengan 5 perlakuan dan 3 ulangan.

Hasil penelitian menunjukkan bahwa pemberian powder *Nannochloropsis* sp. dengan dosis yang berbeda memberikan perbedaan nyata ($p < 0,05$) terhadap rasio konversi pakan, sintasan, tingkat perlindungan relatif dan rerata waktu kematian setelah di uji tantang dengan bakteri patogen *Vibrio alginolyticus*. Sintasan hidup tertinggi pada perlakuan NA (15g/kg) pakan. Nilai tertinggi tingkat perlindungan relatif dan rerata waktu kematian juga terdapat pada perlakuan 15g/kg. Sintasan hidup pada perlakuan kontrol negatif dan positif hanya mencapai 63,89% dan 69,44 sedangkan perlakuan NA (15 g/kg) memiliki sintasan hidup mencapai 88,89%.

Kata kunci : *Nannochloropsis* sp., *Vibrio alginolyticus*, *Lates calcarifer*.

PENDAHULUAN

Ikan kakap putih dapat dibudidayakan di perairan payau maupun perairan laut. Namun budidaya ikan kakap putih di Indonesia masih mengalami kendala dalam penyediaan benih secara kontinu. Kendala budidaya ini salah satunya disebabkan oleh serangan penyakit pada kegiatan budidaya ikan kakap putih (Jerry, 2014).

Wabah penyakit pada kegiatan budidaya dipengaruhi oleh interaksi yang tidak seimbang antara ikan, lingkungan, dan patogen (Austin & Austin 2012). Saat fase benih, ikan kakap mudah stres sehingga pertahanan tubuh ikan mengalami penurunan. Stres diakibatkan kondisi lingkungan yang memburuk serta ditunjang oleh keberadaan patogen seperti bakteri, jamur, parasit, dan virus, sehingga penyakit akan mudah menginfeksi ikan (Affandi & Tang 2002)

Selain itu yang menghambat perkembangan usaha budidaya ikan Kakap Putih di Indonesia adalah kualitas pakan buatan (Berian. et al, 2012). Untuk mendapatkan pertumbuhan ikan yang optimum perlu ditambahkan pakan tambahan yang berkualitas tinggi, yaitu pakan yang memenuhi kebutuhan nutrisi ikan. Nilai gizi pakan ikan umumnya dilihat dari komposisi zat gizinya, seperti kandungan protein, lemak, karbohidrat, vitamin dan mineral (Nur, 2011)

Jenis bakteri yang sering menyerang kakap putih adalah *vibrio alginolyticus* (Novriadi, 2010). *Vibrio* adalah agen penyebab penyakit vibriosis yang menyerang hewan laut seperti ikan, udang, dan kerangkerangan. *Vibrio alginolyticus* merupakan bakteri yang paling sering menginfeksi kakap putih sehingga menyebabkan kematian masal (Taslihan et.al, 2000).

Penanganan penyakit jenis bakteri dapat diberi antibiotik, namun penggunaan antibiotik dapat menyebabkan resistensi pada bakteri dan residunya berbahaya untuk manusia. Oleh karena itu, berbagai bahan herbal digunakan dalam pencegahan penyakit jenis bakterial. Bahan herbal difungsikan dalam memicu ketahanan tubuh ikan terhadap penyakit sehingga mampu menahan serangan akibat bakteri. salah satu alternatif pencegahan *patogen* yang aman baik bagi ikan, manusia dan lingkungan, yaitu dengan pemberian pakan tambahan dari bahan alami menggunakan mikroalga (*Nannochloropsis* sp.)

Kandungan protein dan vitamin pada mikroalga memiliki potensi sebagai ketahanan tubuh ikan dan pertumbuhan ikan. *Nannochloropsis* sp memiliki sejumlah kandungan pigmen dan nutrisi seperti protein (52,11%), karbohidrat (16%), lemak (27.64%), dan vitamin C (0,85%) (Isnanstyo dan Kurniastuti, 1995).

Nannochloropsis sp. mengandung EPA sebesar 44,26%, memiliki kandungan Vitamin B12, dan memiliki total kandungan omega 3 sebesar 42,7 %. Kandungan nutrisi pada *Nannochloropsis* sp. khususnya untuk EPA, Vitamin B12, dan omega 3 tidak dimiliki oleh kedua mikroalga lainnya yang diuji yaitu *Tetraselmis chuii* dan *Chaetoceros* sp. (Sutomo 2000 et.al, 2007). Pemberian pakan yang memiliki kandungan kualitas gizi dan aman bagi lingkungan perairan merupakan alternatif lain dalam pengendalian penyakit dan lambatnya pertumbuhan ikan kakap putih, pemberian pakan yang ditambahkan dari bahan herbal dalam hal ini powder *Nannochloropsis* sp. perlu dilakukan untuk mencegah serangan penyakit vibriosis dan lambatnya pertumbuhan ikan kakap putih.

METODE PENELITIAN

Ikan uji yang digunakan adalah benih ikan kakap putih (*Lates calcarifer*) dengan berat $8,29 \pm 3,5$ g/ekor sebanyak 750 ekor. Wadah yang digunakan dalam penelitian ini adalah 15 waring berukuran $50 \times 50 \times 50$ cm³ dan bak fiberglass berbentuk persegi panjang dengan volume 2000 liter sebanyak 5 unit. Setiap waring diisi benih ikan kakap putih sebanyak 50 ekor. Metode penelitian yang digunakan adalah rancangan acak lengkap (RAL) faktorial, yaitu dengan 5 perlakuan dengan masing-masing 3 ulangan.

Pakan yang digunakan berupa pakan komersil dicampur dengan powder *Nannochloropsis* sp. yang ditambah progol sebagai perekat (binder). Setelah tercampur kemudian dikeringkan dalam suhu ruang, setelah kering pakan dapat diberikan ke ikan uji. Menggunakan kombinasi dosis:

1. Pakan komersil tanpa tambahan powder *Nannochloropsis* sp. maupun binder
2. Pakan komersil yang hanya ditambahkan binder (progol) 5g/kg pakan
3. Pakan komersil yang ditambahkan powder *Nannochloropsis* sp. 15g/kg. dan binder (progol) 5g/kg
4. Pakan komersil yang ditambahkan powder *Nannochloropsis* sp. 30g/kg. dan binder (progol) 7,5g/kg
5. Pakan komersil yang ditambahkan powder *Nannochloropsis* sp. 60g/kg. dan binder (progol) 10g/kg

Persiapan Ikan Uji

Waring berukuran $50 \times 50 \times 50$ cm³ sebanyak 15 unit dan bak fiberglass berbentuk persegi panjang dengan volume 2000 liter sebanyak 5 unit disiapkan. Bak fiberglass yang akan digunakan disterilisasi dengan cara dicuci dan didesinfeksi menggunakan kaporit kemudian dibilas dengan air tawar. Ikan uji disiapkan, yaitu ikan kakap putih berat $8,29 \pm 3,5$. Ikan diaklimatisasi terlebih dahulu selama satu minggu. Ikan dipelihara dalam wadah dan diberi aerasi, serta diberi pakan pellet komersil 3 kali sehari, pagi 07.30 WIB, siang 12:30 WIB dan sore pukul 15.30 WIB

Uji Tantang

Uji tantang dilakukan setelah 60 hari pemberian vaksin, dengan menginfeksi bakteri *V. Akginolyticus* sebanyak $6,7 \times 10^9$ cfu/ml yang diperoleh dari hasil LD₅₀. Setelah diuji tantang, ikan dipelihara selama 7 hari dan dilakukan pengamatan ,sintasan (survival rate), relatif percent survival (RPS), mean time to deth (MTD).

Analisis Data

Data dianalisis menggunakan aplikasi SPSS dan uji lanjut untuk beda nyata menggunakan uji *least signification different* (LSD). Hasil Pengamatan yang didapatkan dari setiap perlakuan dianalisis secara analisis dan deskriptif. Data hasil utama yang ingin didapatkan adalah sintasan hidup (SR) sebelum dan sesudah uji tantang, RPS, RWK, laju pertumbuhan spesifik, dan rasio konversi pakan terhadap perlakuan normal atau perlakuan kontrol.

HASIL DAN PEMBAHASAN

Performa Pertumbuhan

Hasil penelitian pengaruh penambahan powder *Nannochloropsis sp.* pada pakan komersial terhadap performa pertumbuhan ikan kakap putih meliputi parameter :rerata bobot awal, rerata bobot akhir, jumlah konsumsi pakan, laju pertumbuhan spesifik, rasio konversi pakan dan kelangsungan hidup dapat dilihat pada Table 1.

Parameter	PERLAKUAN				
	K-	K+	NA	NB	NC
Bobot awal rata-rata (g/ekor)	8,29±3,50a	8,95±3,35a	8,38±2,71a	8,35±2,52a	8,33±2,22a
Bobot ahir rata-rata (g/ekor)	51,21±8,72a	61,48±12,48b	67,38±11,18ab	58,04±10,49b	52,08±13,49a
Jumlah konsumsi pakan	29,72±7,19a	32,90±6,45b	36,54±10,35b	30,15±8,18a	24,56±5,52b
Laju pertumbuhan Spesifik	6,29±0,27a	6,59±0,28b	6,79±0,21b	6,50±0,20a	6,28±0,31a
Rasio Konversi Pakan	1,95±0,18ab	1,55±0,25b	1,30±0,09a	1,25±0,03a	1,26±0,04a
Kelangsungan hidup (%)	78,00±2,00a	89,00±1,15b	90,67±1,15b	92,00±2,00b	94,67±4,16b

Keterangan huruf yang berbeda dalam baris yang sama setelah angka standar deviasi, menunjukkan perbedaan nyata antar perlakuan ($p < 0,05$).

Hasil penelitian penambahan powder *Nannochloropsis sp.* pada pakan ikan kakap putih berpengaruh terhadap pertumbuhan atau bobot akhir tubuh ikan kakap putih, rasio konversi pakan namun pada laju pertumbuhan spesifik dan kelangsungan hidup tidak berpengaruh secara signifikan.

Rata-rata laju pertumbuhan spesifik perlakuan K- tanpa tambahan powder dan binder yaitu 6,29% kemudian mengalami kenaikan pada perlakuan K+ dengan rata-rata laju pertumbuhan spesifik 6,79 %. Perlakuan NA dosis powder *Nannochloropsis sp.* 15% mengalami kenaikan dengan rata-rata 6,79% perlakuan NB powder *Nannochloropsis sp.* 30% laju pertumbuhan spesifik 6,50%. Perlakuan NC dosis powder *Nannochloropsis sp.* 60% justru mengalami penurunan laju pertumbuhan spesifik 6,28% hal tersebut diduga karena pada awal penelitian ikan kakap putih pada perlakuan NC belum sebegitu banyak mengonsumsi pakan yang sudah ditambahkan powder *Nannochloropsis sp.* sehingga berdampak pada laju pertumbuhan spesifik.

Laju pertumbuhan spesifik meningkat secara signifikan ($p < 0,05$) pada ikan kakap putih antar perlakuan. Hal ini disebabkan karena kandungan nutrisi pada pakan yang

diberikan sudah memenuhi kebutuhan untuk pertumbuhan ikan kakap putih, sehingga laju pertumbuhan ikan kakap putih terus meningkat. Protein pada pakan yang diberikan pada ikan kakap putih berkisar 35% - 39. Sesuai dengan pernyataan Ali (2009) menyatakan kebutuhan protein pakan ikan kakap putih sebesar 30% - 35%

Rata-rata rasio konversi pakan perlakuan K- yaitu 1,95 kemudian mengalami penurunan pada perlakuan K+ dengan rata-rata rasio konversi pakan 1,55. Perlakuan NA dosis powder *Nannochloropsis sp.* 15% mengalami penurunan dengan rata-rata 1,30 kemudian perlakuan NB dosis powder *Nannochloropsis sp.* 30% juga mengalami penurunan rasio konversi pakan 1,25. perlakuan NC dosis powder *Nannochloropsis sp.* 60% mengalami kenaikan rasio konversi pakan 1,26. Semakin tinggi penambahan powder *Nannochloropsis* semakin mengalami penurunan pada rasio konversi pakan ikan kakap putih.

Penyebab tinggi atau rendahnya nilai rasio konversi pakan disebabkan karena pakan tidak dicerna atau jenis pakan yang kurang disukai dan pemberian pakan yang berlebihan tidak sesuai dengan takaran menyebabkan nilai rasio konversi pakan tinggi (Sutarmat, 2006). Nilai pertumbuhan erat kaitannya dengan konversi pakan, nilai FCR yang semakin kecil menunjukkan mutu pakan yang semakin baik yang mana tingkat pencernaan pakan semakin tinggi. Sebaliknya, apabila nilai pertumbuhan yang rendah memiliki nilai konversi pakan yang besar (Heptarina dkk., 2010).

Rata-rata sintasan hidup perlakuan K- yaitu 78% kemudian mengalami peningkatan pada perlakuan K+ dengan rata-rata sintasan hidup 89%. Perlakuan NA dosis powder *Nannochloropsis sp.* 15% mengalami peningkatan dengan rata-rata 90,67% kemudian perlakuan NB dosis powder *Nannochloropsis sp.* 30% juga mengalami peningkatan sintasan hidup 92%, perlakuan NC dosis powder *Nannochloropsis sp.* 60% mengalami peningkatan sintasan hidup 94,67%. Semakin tinggi penambahan powder dosis *Nannochloropsis sp.* semakin tinggi pula sintasan hidup ikan kakap putih.

Ikan kakap putih dapat hidup dengan nilai 95% diduga karena kebutuhan akan asam lemak ω 3-HUFA pada benih kakap putih tersebut tercukupi dibandingkan perlakuan lain. Berdasarkan analisa pada laboratorium, *Nannochloropsis sp.* memiliki kandungan asam lemak ω 3- HUFA dengan kandungan EPA sebesar dan kandungan DHA. Dengan demikian kebutuhan asam lemak ω 3- HUFA pada benih kakap putih terpenuhi secara optimal, sehingga kemampuan adaptasi dan daya tahan meningkat yang akhirnya menyebabkan tingkat mortalitas lebih rendah. Hal ini sesuai dengan pernyataan Isnansetyo (1992) yang menyatakan defisiensi ω 3-HUFA pada ikan dapat menyebabkan kematian dan terhambatnya pertumbuhan.

Sintasan (survival rate)

Hasil kelangsungan hidup atau survival rate dapat setelah uji tantang dilihat pada tabel 2.

Perlakuan	Ulangan			Rata-rata Sintasan (%)
	1	2	3	
K-	66.67	75.00	50.00	63.89 ± 12.73 ^a
K+	75.00	75.00	58.33	69.44 ± 9.62 ^a
NA	91.67	91.67	83.33	88.89 ± 4.81 ^b
NB	83.33	91.67	83.33	86.11 ± 4.81 ^b
NC	75.00	83.33	83.33	80.56 ± 4.81 ^b

Keterangan huruf yang berbeda dalam kolom yang sama setelah angka standar deviasi, menunjukkan perbedaan nyata antar perlakuan ($p < 0,05$)

Hasil pengamatan menunjukkan nilai kelangsungan hidup tertinggi diperoleh pada NA yaitu mencapai 88,89%. Hal tersebut diduga karena powder *Nannochloropsis* sp. mengandung Vitamin C, Vitamin B12, EPA lemak $\omega 3$ - HUFA , EPA, DHA, antioksidan, karotenoid dan peridinin dapat meningkatkan kesehatan ikan. Dahoklory *et al.*, (2014) menyatakan, bahwa pemberian peridinin dapat meningkatkan daya tahan tubuh dan kesehatan ikan.

Hasil perhitungan sintasan menunjukkan bahwa perlakuan NA merupakan perlakuan terbaik dengan nilai kelulus hidupan 88,89%, sedangkan pada perlakuan K- 63,89% dan K+ 69,44%. Penyebabnya diduga karena powder *Nannochloropsis* sp. mengandung vitamin yakni vitamin C dan B12 pakan dapat meningkatkan kekebalan tubuh, sehingga tingkat kelulus hidupan meningkat.

Tingkat Perlindungan Relatif (TPR)

TPR menunjukkan bahwa hasil pengamatan tingkat kelangsungan hidup relative pada ikan yang diberi pakan powder *Nannochloropsis* sp. menunjukkan hasil lebih dari 70% dapat dilihat pada tabel 3.

Perlakuan	Ulangan			Rata-rata Sintasan (%)
	1	2	3	
K-	66.67	75.00	50.00	63.89 ± 12.73 ^a
K+	75.00	75.00	58.33	69.44 ± 9.62 ^a
NA	91.67	91.67	83.33	88.89 ± 4.81 ^b
NB	83.33	91.67	83.33	86.11 ± 4.81 ^b
NC	75.00	83.33	83.33	80.56 ± 4.81 ^b

Keterangan huruf yang berbeda dalam kolom yang sama setelah angka standar deviasi, menunjukkan perbedaan nyata antar perlakuan ($p < 0,05$)

Hasil uji sidik ragam pada tingkat perlindungan relatif (TPR) selama penelitian menunjukkan bahwa ada beda nyata ($P < 0,05$) antar perlakuan. TPR tertinggi ditunjukkan

oleh perlakuan NA 87,27%, kemudian disusul oleh NB (83,64%), sedangkan TPR terendah ditunjukkan oleh perlakuan K- yaitu 48,41%.

Hal tersebut diduga karena mikroalga (*Nannochloropsis oculata*) mempunyai kandungan asam-asam lemak, asam palmitat, asam oleat, asam linoleat, asam arakhidonat sebagai antibakteri yang dapat merusak dinding bakteri sehingga bisa menyebabkan kematian bakteri (Surendhiran et.al.2014).

Asam palmitat memiliki sifat hidrofil maupun hidrofobik, tetapi sifat hidrofobiknya jauh lebih besar dibandingkan sifat hidrofiliknya. Struktur yang demikian ini akan menyebabkan terganggunya proses osmosis maupun difusi pada membran sel mikroba tersebut (Nufailah,2008).

Asam arakidonat akan diesterifikasikan menjadi bentuk fosfolipid dan lainnya berupa kompleks lipid oleh membran sel. Pada biosintesis eikosanoid, asam arakidonat akan dibebaskan dari sel penyimpanan lipid oleh hasil *hydrolase*. Mekanismenya merusak sistem enzim dan menimbulkan kerusakan pada protein sitoplasma (Mansjoer,et.al 2003).

Rerata Waktu Kematian (RWK)

Hasil dari rerata waktu kematian yang telah diuji tantang menggunakan bakteri *Vibrio alginolyticus* selama 7 hari dapat dilihat pada tabel 3.

Perlakuan	Ulangan			Rata-rata Sintasan (%)
	1	2	3	
K-	66.67	75.00	50.00	63.89 ± 12.73 ^a
K+	75.00	75.00	58.33	69.44 ± 9.62 ^a
NA	91.67	91.67	83.33	88.89 ± 4.81 ^b
NB	83.33	91.67	83.33	86.11 ± 4.81 ^b
NC	75.00	83.33	83.33	80.56 ± 4.81 ^b

Keterangan huruf yang berbeda dalam kolom yang sama setelah angka standar deviasi, menunjukkan perbedaan nyata antar perlakuan ($p < 0,05$)

RWK tertinggi ditunjukkan oleh perlakuan NA yaitu 96 jam (4 hari) kemudian disusul oleh NB yaitu jam (3 hari), NC mencapai jam (3 hari,8 jam), dan RWK terendah ditunjukkan oleh perlakuan kontrol (tanpa powder *Nannochloropsis sp.*) yaitu 32 jam (1 hari,8 jam). Hasil ini menunjukkan bahwa penambahan powder *Nannochloropsis sp.* pada pakan dapat meningkatkan ketahanan hidup ikan kakap putih terhadap *V.algynoliticus*, dibandingkan dengan perlakuan yang tidak ditambah powder *Nannochloropsis sp.*

Peningkatan MTD pada ikan kakap putih yang diberi pakan dengan tambahan powder *Nannochloropsis sp* terjadi karena powder *Nannochloropsis sp.* memiliki kandungan senyawa aktif yang berkhasiat sebagai anti inflamasi, yaitu flavonoid, omega-3 dan *oxypilins*. Senyawa flavonoid merupakan salah satu bahan aktif yang terdapat pada ekstrak *Nannochloropsis sp.* (Yanuhar et.al 2011).

Flavonoid dapat berfungsi sebagai agen antiinflamasi. Flavonoid berfungsi untuk membatasi pelepasan mediator inflamasi yang dilakukan melalui penghambatan

siklooksigenase dan lipooksigenase sehingga terjadi pembatasan jumlah sel inflamasi yang bermigrasi ke jaringan perlukaan (Yanuhar et.al 2011).

Reaksi inflamasi akan berlangsung lebih singkat dan kemampuan proliferasi dari TGF- β tidak terhambat, sehingga proses proliferasi dapat segera terjadi (Indrasawary. 2011). Mekanisme flavonoid dalam menghambat proses inflamasi terjadi melalui dua cara, yaitu dengan menghambat permeabilitas kapiler dan menghambat metabolisme asam arakidonat dan sekresi ezim lisosom dari sel neutrofil dan sel endothelial (Kurniawati. 2005.)

Mekanisme *oxylipin* dalam menghambat inflamasi yaitu dengan menghambat permeabilitas kapiler dan menghambat metabolisme asam arakidonat serta sekresi enzim lisosom dari sel neutrofil dan sel endothelial. Sebagai antioksidan, *oxylipin* mempunyai gugus hidroksi fenolik dalam struktur molekulnya, dimana akan menghambat kerja enzim yang terlibat dalam reaksi produksi anion superoksida, misalnya xantin oksidase dan proteinkinase. Selain itu, senyawa aktif ini juga menghambat siklooksigenase, lipooksigenase, mikrosomal monooksigenase, glutathion-S-transferase, mitokondrial suksinoksidase, NADH oksidase (Hertiani, et.al.2010)

KESIMPULAN DAN SARAN

Penambahan powder *Nannochloropsis sp.* dengan konsentrasi 1,5% (15g/kg) merupakan dosis paling efektif dalam peningkatan ketahanan tubuh dan performa pertumbuhan ikan kakap putih dengan tingkat perlindungan relatif $87,27 \pm 6,30$, rerata waktu kematian 96.00 ± 24.00 dan kelangsungan hidup sebelum dan sesudah uji tantang 90,67% dan 89,88%.

Perlu kajian menggunakan ikan, metode dan binder lainnya yg lebih efektif dan efisien dalam penggunaan powder *Nannochloropsis sp.*

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SYNTHESIS, CHARACTERIZATION, AND ANTIOXIDANT ACTIVITY OF SOME ORGANOTIN(IV) 2-NITROBENZOATE USING THE 2,2-DIPHENYL-1-PICRYL-HYDRAZYL (DPPH) METHOD

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Abstract

Synthesis, characterization, and antioxidant activity of diphenyltin(IV) di-2-nitrobenzoate (**2**), dibutyltin(IV) di-2-nitrobenzoate (**4**), and triphenyltin(IV) 2-nitrobenzoate (**6**) using the 2,2-diphenyl-1-picryl-hydrazyl (DPPH) method has been successfully carried out. All compounds were well characterized by some spectroscopy techniques of UV, IR, NMR and based on physical technique by microelemental analysis. The result showed that diphenyltin(IV) di-2-nitrobenzoate was the most active in the antioxidant activity test, with an IC₅₀ value of 8.6 µg/mL compared to the other compounds in which the dibutyltin(IV) di-2-nitrobenzoate and triphenyltin(IV) 2-nitrobenzoate have IC₅₀ values of 12.29 µg/mL and 27.28 µg/mL, respectively, which indicated that compounds **6** and **9** were categorized active antioxidant activity. However the IC₅₀ values of these compounds were higher than the positive control, ascorbic acid with IC₅₀ value of 0.66 µg/mL.

Keywords: antioxidant activity, DPPH method, organotin(IV) 2-nitrobenzoate, synthesis.

1. Introduction

Organotin compounds are compounds that contain at least one direct covalent bond between the carbon atom (C) of the organic group which is attached to the central Sn atom. Organotin compounds have been known to have wide range of applications and are among the most widely used of organometallic compounds. Organotin(IV) compounds have been reported to show many biological activities [1-4]. Among the various organotin(IV) complexes with biological molecules, organotin(IV) carboxylate complexes have received special attention because these compounds have better biological activity compared to other organotin(IV) complexes with various ligands [5-14].



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Antioxidants are compounds that can fight or reduce the negative effects of oxidants. Antioxidants work by contributing one electron to an oxidant compound so that the activity of the oxidant compound can be inhibited [15]. Antioxidant compounds can play a role in reducing oxidative damage associated with aging, cardiovascular disease, cancer, inflammation, skin diseases, and malaria, prompting some searches for metal-based antioxidant drug compounds, especially organotin(IV) to be developed [15-17].

Based on the reactivity of organotin compounds, many researches have been attempted to utilize them in some biological activities, one of them is as an antioxidant. Therefore, in this paper, we reported the antioxidant activity of some organotin(IV) 2-nitrobenzoate using the DPPH method.

2. Experimental

2.1. Materials and characterisation

All reagents used were AR grade. Diphenyltin(IV) oxide ($[(C_6H_5)_2SnO]$) (1), dibutyltin(IV) oxide ($[(C_6H_5)_2SnO]$) (3) and triphenyltin(IV) oxide ($[(C_6H_5)_3SnCl]$) (5), 2-nitrobenzoic acid were obtained from Sigma, sodium hydroxide (NaOH) and methanol (CH₃OH) were JT Baker products, and the control ascorbic acid were from Sigma-Aldrich. All chemical were used as received without further purification.

The measurement of IR spectra were conducted using Bruker VERTEX 70 FT-IR spectrophotometer in the range 4000-400 cm^{-1} with KBr pellets. The UV spectra was measured with a UV-Shimadzu UV-245 Spectrophotometer on UV region. The measurement was performed in 1mL quartz-cells. The solvent used was methanol and sample concentration of 1.0×10^{-5} M were prepared. The ¹H and ¹³C NMR spectra were recorded using a Bruker AV 600 MHz NMR (600 MHz for ¹H and 150 MHz for ¹³C). DMSO-D₆ was used as solvent in the experiments and measured at 298K. The number of runs used for ¹H experiments were 32 with reference at DMSO signal at 2.5 ppm, while the ¹³C were 1000-4000 scans with the reference of DMSO signal at 39.5 ppm. The microelemental analysis (CHNS) was carried out using Fision EA 1108 series elemental analyser.

2.2. Preparation of organotin(IV) 2-nitrobenzoate

The organotin(IV) 2-nitrobenzoate compounds used in this work were prepared based on the procedures previously reported [8, 9, 11-13]. These procedures were obtained as adaptation from the work available in the literature [10]. For example the procedure in the preparation of diphenyltin(IV) di-2-nitrobenzoate was as follows:

0.4605 g (1.5 mmol) compound **1** in 20 mL of methanol was added with 2 mole equivalents of 2-nitrobenzoic acid (0.498 g) and was refluxed for 4 hours at 60 – 61°C. After removal of the solvent by rotary evaporator, the compound $[(C_6H_5)_2Sn(2-OOCC_6H_4(NO_2))_2]$ (**2**) was obtained as white solid and was dried *in vacuo* until they are ready for analysis and further use for antioxidant activity test. The yield was 0.835 g (92 %). The same procedure was also adapted in the preparation of dibutyltin(IV), $[(C_4H_9)_2Sn(2-OOCC_6H_4(NO_2))_2]$. For the triphenyltin(IV) derivatives, $[(C_6H_5)_3Sn(OOCC_6H_4(NO_2))]$, one mole equivalent of 2-nitrobenzoic acid was added.

2.3. Antioxidant Activity Test

Antioxidant activity test by DPPH method was performed according to method used by others [15– 17]. Briefly, the compounds to be tested were dissolved in methanol at concentrations of 2; 4; 8; 16, and 32 μ M. To each test solution, DPPH (0.1 mM in methanol) was added and mixed thoroughly. The solution was left aside for 30 min. The absorbance of the mixture at a wavelength of 517 nm was measured using a UV-vis spectrophotometer. Antioxidant activity was calculated as the percentage of inhibition against DPPH. Percentage inhibition or percentage of DPPH radical capture activity was calculated using Equation 1:

$$\text{Percentage inhibition} = \left\{ \frac{\text{Control absorbance} - \text{Sample absorbance}}{\text{Control absorbance}} \right\} \times 100\%.$$

The IC₅₀ of each sample concentration was calculated using the linear regression equation. The sample concentration was plotted in the X axis and percentage of inhibition in the y axis. From the equation $y = a + bx$, the value of IC₅₀ was calculated using Equation 2.

$$IC_{50} = \frac{50 - a}{b} \quad (2)$$

where y is the percentage inhibition (50), a is the intercept (intersection of lines the y axis), b is the slope, and x is the concentration.

3. Results and discussion

3.1 Characterisation of compounds

All synthesised compounds were well characterized with some spectroscopy techniques of UV, IR, NMR (¹H and ¹³C) as well as based on the microelemental analysis. The results of each analysis are tabulated on Tables 1–4. The structure of the compounds which have been prepared are shown in Figure 1.

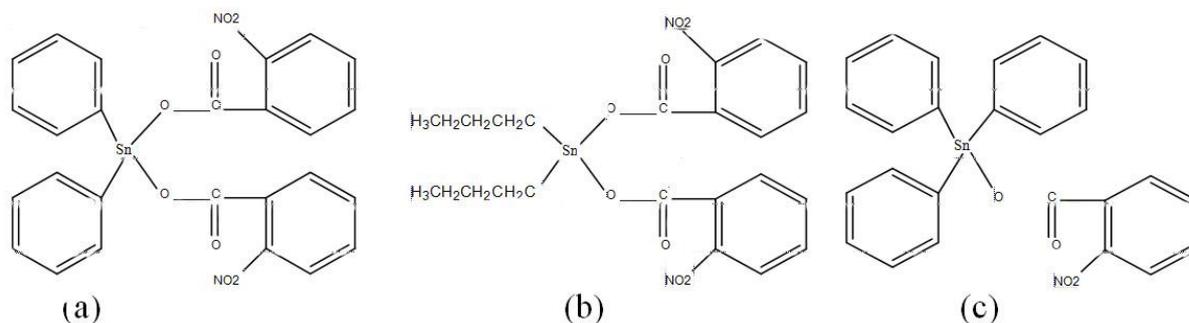


Figure 1. (a) diphenyltin(IV) di-2-nitrobenzoate; (b). dibutyltin(IV) di-2-nitrobenzoate; (c). triphenyltin(IV) 2-nitrobenzoate

Table 1. The microanalytical data of the organotin(IV) compounds synthesized

	Compound Elemental analysis found		
	(calculated)		
	C	H	N
$[(C_6H_5)_2Sn(o-C_6H_4(NO_2)COO)_2]$ (2)	51.40 (51.57)	2.96 (2.98)	4.57 (4.63)
$[(n-C_4H_9)_2Sn(o-C_6H_4(NO_2)COO)_2]$ (4)	46.63 (46.73)	3.12 (3.19)	4.89 (4.96)
$[(C_6H_5)_3Sn(o-C_6H_4(NO_2)COO)]$ (6)	58.08 (58.14)	3.65 (3.68)	2.67 (2.71)

Table 2. 1H and ^{13}C spectra of the compounds synthesized

Compounds	H in butyl or phenyl (ppm)	H in benzoate (ppm)	C in butyl, phenyl and benzoate (ppm)
$[(C_6H_5)_2Sn(o-C_6H_4(NO_2)COO)_2]$ (2)	H2 & H6 = 7.61 (d, 4H); H3 & H5 = 7.50 (t, 4H); H4 = 7.39 (t, 2H)	H10-13 (m) = 7.82 - 7.95 (m)	C(phen) C2 & 6: 131.8, C3 & 5 = 129.7, C4 = 127.1; C7: 166.1; C8: 138.9; C9 = 139.2, C10 = 132.5; C11: 128.9, C12: 128.1; C13: 130.2;
$[(n-C_4H_9)_2Sn(o-C_6H_4(NO_2)COO)_2]$ (4)	H_α & H_β = 1.41-1.62 (m); H_γ = 1.30 (m); H_δ = 0.95 (t)	7.35-7.85 (m)	C_α = 26.3; C_β = 24.6; C_γ = 22.9; C_δ = 14.2; C7: 166.6; C8: 138.3; C9 = 138.8; C10 = 131.7; C11 = 128.1; C12 = 127.6; C13 = 129.7
$[(C_6H_5)_3Sn(o-C_6H_4(NO_2)COO)]$ (6)	H2 & H6 = 7.58 (d, 6H); H3 & H5 = 7.45 (t, 6H); H4 = 7.31 (t, 3H)	7.86 - 7.92 (d)	C (phen) C2&6 = 131.1; C3 & 5 = 129.4, C4 = 127.5; C7: 167.8; C8: 137.6; C9: 138.1; C10: 131.1; C11: 129.3; C12: 128.0; C13: 129.

Table 3. The characteristic and important IR bands of the organotin(IV) compounds (cm^{-1}) synthesized

Compound	2	4	6	References
Sn-O	594.2	435.9	765.61	800-400
Sn-O-C	1243.1	1028.3	1243.42	1050-900
Sn-Bu	-	678.4	-	740-660
CO ₂ asym	1532.7	1418.7	1558.9	1600-1400
CO ₂ sym	1661.1	1560.9	1631.47	1700-1550
C-H	2955		-	1450, 730
aliphatic	2868			2960 - 2850
Phenyl	1467.8;	-	751.5	729.6 1429.2

Table 4. The λ_{max} of the UV-Vis spectra of the organotin(IV) compounds

Compound	λ_{max} (nm)
[(C ₆ H ₅) ₂ Sn(o-C ₆ H ₄ (NO ₂)COO) ₂] (2)	236 and 278
[(n-C ₄ H ₉) ₂ Sn(o-C ₆ H ₄ (NO ₂)COO) ₂] (4)	235 and 275
[(C ₆ H ₅) ₃ Sn(o-C ₆ H ₄ (NO ₂)COO)] (6)	237 and 282

An example of characterization of the products obtained was analyzed using FT-IR spectroscopy in the frequency range 4000 - 400 cm^{-1} . The characteristic vibration of starting material (compound **1**) is the present of the main absorption of the Sn-O bond in the region 440-390 cm^{-1} and it was observed that in **1** appeared at a frequency of 417.4 cm^{-1} . When compound **1** is converted into compound **2**, the strong band 417.4 cm^{-1} is disappeared and a new main absorption appears at 594.2 cm^{-1} which is a typical absorption. from the appearance of the Sn-O bond in compound **2** where oxygen from carboxylic group has bound to Sn atom. While the absorption of phenyl and C = C vibrations are still appeared as expected. Upon formation of compound **2**, the present very strong vibration band in the region of 1661.1 cm^{-1} is a typical of C=O bond vibration in compound **2**. The presence of vibration from Sn-O-C bond at 1243.1 cm^{-1} supported the analysis. The same observations were also observed in the formation of compound **4** and **6**, and these data are agreed to the reported values in the literature [8, 9, 11-13, 18]. The results of analysis with UV and NMR also indicated that all compounds prepared are in agreement with similar compounds reported in the literature [5, 8, 9, 11-13, 18-20]

3.2 Antioxidant activity test

In the antioxidant activity test using the DPPH method, the three synthesized compounds were tested in concentration variation of 2, 4, 8, 1.6, 3.2 μM . After the

absorbance in each measurement is obtained, the % inhibition can be calculated and the data are shown in Tables 5, 6, and 7. From these tables, then the IC₅₀ (Inhibitory Concentration of 50%) value can be calculated.

Table 5. The results of the antioxidant activity test for diphenyltin(IV) di-2-nitrobenzoate

	Concentration	Sample	Control	%Inhibition
	μM	Absorbance	Absorbance	
1.	2	0.534	0.959	45.5102
2.	4	0.521	0.959	46.83673
3.	8	0.506	0.959	48.36735
4.	16	0.493	0.959	49.69388
5.	32	0.386	0.959	60.61224

Table 6. The results of the antioxidant activity test of the compound dibutyltin(IV) di-2-nitrobenzoate

	Concentration	Sample	Control	%Inhibition
	μM	Absorbance	Absorbance	
1.	2	0.512	0.959	47.7551
2.	4	0.510	0.959	47.95918
3.	8	0.505	0.959	48.46939
4.	1	0.495	0.959	49.4898
5.	3	0.479	0.959	51.12245

Table 7. The results of the antioxidant activity test of the triphenyltin(IV) 2-nitrobenzoate compound

	Concentration	Sample	Control	%Inhibition
	μM	Absorbance	Absorbance	
1.	2	0.507	0.95	48.26531
2.	4	0.506	0.95	48.36735
3.	8	0.505	0.95	48.46939
4.	16	0.498	0.95	49.18367
5.	32	0.491	0.95	49.89796

To find out the value of IC, the % inhibition value is inserted to the linear regression equation curve and the line equation $y = 50$ (50% inhibition) is generated in the equation and the value of x (concentration) is obtained. The minimum concentration is the x value of the test compound which can be used to inhibit radicals by 50%. The results on the antioxidant activity of the synthesized compounds compared to ascorbic acid are presented in Table 8 and the linear regression curve in Figure 2.

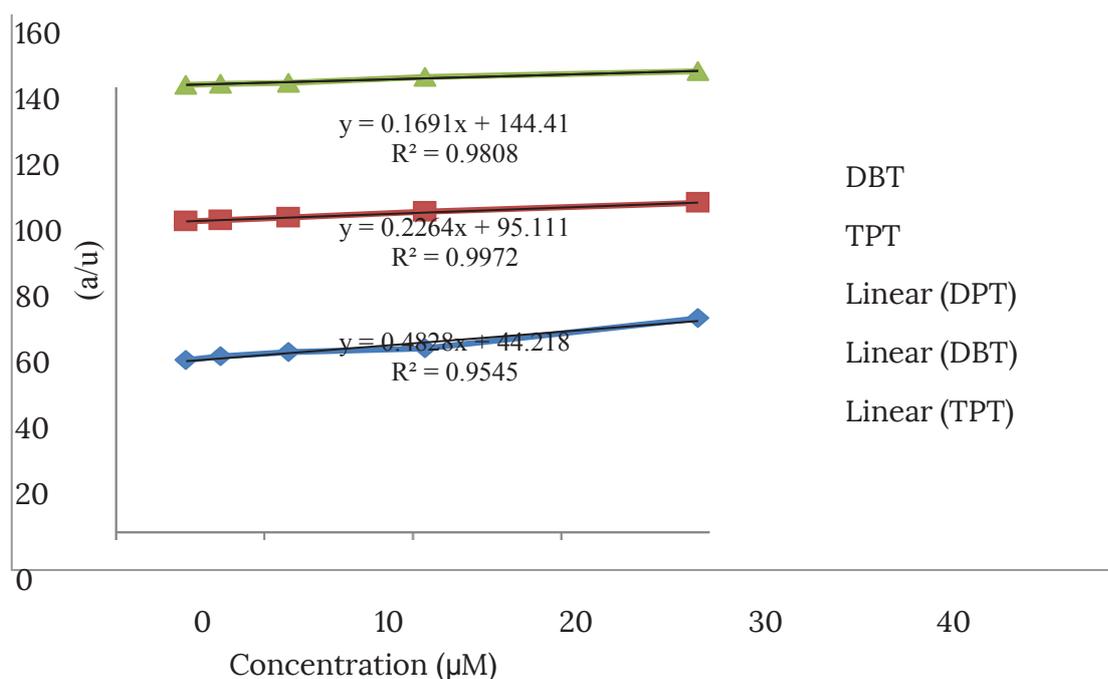


Figure 2. Linear regression curve for antioxidant activity test of all compounds tested
DPT = diphenyltin(IV); DBT = dibutyltin(IV); TPT = triphenyltin(IV)

Table 8. The results of the antioxidant activity test using the DPPH method.

Compound	IC ₅₀ (µM)	IC ₅₀ (µg/mL)
[(C ₆ H ₅) ₂ Sn(o-C ₆ H ₄ (NO ₂)COO) ₂] (2)	14.21	8.6
[(n-C ₄ H ₉) ₂ Sn(o-C ₆ H ₄ (NO ₂)COO) ₂] (4)	21.68	12.29
[(C ₆ H ₅) ₃ Sn(o-C ₆ H ₄ (NO ₂)COO)] (6)	27.28	27.28
Ascorbic acid	3.74	0.66

Based on the data in Table 8, the IC₅₀ value for compounds **2**, **4** and **6** are 8.6; 12.29; 27.28 µg/mL, respectively. Therefore, compound **2** is categorized as to be very active while compound **4** and **6** categorized as active compound. This is based on categorization stated by Phongpaichit *et al.* [21] that compound having IC₅₀ value <10 µg/mL is very active compound as antioxidants and IC₅₀ value of 10–50 µg/mL is an active compound as antioxidant. However, the IC₅₀ values for the compounds reported are still less active compared to the positive control, ascorbic acid which IC₅₀ of only 0.66 µg/mL.

4. Conclusions

Based on the results of this study, it can be concluded that the three compounds synthesized are potential to be developed as antioxidant although their antioxidant activities are below properties with the following order of activity: diphenyltin (IV) di-2-nitrobenzoate > dibutyltin(IV) di-2-nitrobenzoate > triphenyltin(IV) 2-nitrobenzoate.

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PENGEMBANGAN MODEL PEMBELAJARAN MEANS ENDS ANALYSIS (MEA) UNTUK MENINGKATKAN KEMAMPUAN BERPIKIR REFLEKTIF SISWA

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Abstrak

Penelitian ini merupakan penelitian pengembangan yang bertujuan untuk menghasilkan produk berupa model pembelajaran *Means Ends Analysis (Mea)* yang valid dan praktis dalam meningkatkan kemampuan berpikir reflektif matematis siswa. Desain penelitian ini mengacu pada Borg & Gall. Prosedur penelitian yang dilakukan, yaitu langkah pertama studi pendahuluan meliputi pengumpulan data dan studi literatur, langkah kedua perencanaan produk, langkah ketiga adalah pengembangan desain produk awal, lalu langkah keempat uji coba lapangan awal, dan langkah kelima yaitu revisi hasil uji coba lapangan awal. Subjek penelitian adalah siswa kelas XI SMA Negeri 1 Gedongtataan tahun pelajaran 2019/2020. Data penelitian diperoleh melalui observasi, wawancara, dan angket. Teknik analisis data yang digunakan adalah statistik deskriptif dan Uji-t. Hasil penelitian menunjukkan bahwa desain pengembangan model pembelajaran *Means Ends Analysis (Mea)* memiliki kriteria valid dan praktis. Berdasarkan hasil penelitian dan pembahasan menunjukkan bahwa produk berupa model pembelajaran *Means Ends Analysis (Mea)* yang dikembangkan memenuhi kriteria valid dan praktis.

Kata kunci: *Means Ends Analysis (Mea)*, berpikir reflektif

Abstract

This research is a development research that aims to produce a product in the form of a valid and practical *Means Ends Analysis (Mea)* learning model in improving students' mathematical reflective thinking skills. This research design refers to Borg & Gall. The research procedure is carried out, namely the first step of the preliminary study which includes data collection and literature study, the second step is product planning, the third step is the development of the initial product design, then the fourth step is the initial field trial, and the fifth step is the revision of the results of the initial field trials.

The research subjects were class XI students of SMA Negeri 1 Gedongtataan in the 2019/2020 academic year. Research data were obtained through observation, interviews, and questionnaires. The data analysis technique used is descriptive statistics and t-test. The results showed that the Means Ends Analysis (Mea) learning model development design had valid and practical criteria. Based on the results of research and discussion, it shows that the product in the form of the Means Ends Analysis (Mea) learning model developed meets valid and practical criteria.

Keywords: Means Ends Analysis (Mea), reflective thinking



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PENDAHULUAN

Saat ini dunia sedang menghadapi pandemi virus corona atau covid-19, sehingga telah memberikan tantangan tersendiri bagi lembaga pendidikan di Indonesia. Dalam upaya mengendalikan penyebaran pandemi covid-19, pada pertengahan maret 2020 pemerintah memutuskan untuk menghentikan sementara kegiatan belajar di sekolah. Sesuai dengan surat edaran kemendikbud nomor 4 tahun 2020 tentang pelaksanaan kebijakan pendidikan dalam masa darurat penyebaran corona virus disease (covid-19) menganjurkan untuk melaksanakan proses belajar dari rumah melalui pembelajaran daring. Dalam pelaksanaan pembelajaran dari rumah secara daring, guru dituntut untuk lebih inovatif dalam menyusun langkah-langkah pembelajaran.

Kemampuan berpikir matematika menjadi salah satu tolak ukur tercapainya tujuan pembelajaran matematika. Menurut Soedjadi (Mahasneh, 2013) secara sederhana membedakan tingkatan berpikir dengan menggunakan istilah “berpikir biasa” (*thinking*), “berpikir kritis” (*critical thinking*), “berpikir reflektif” (*reflective thinking*), dan “berpikir kreatif” (*creative thinking*). Dari keempat tingkat tersebut, mungkin tiga tingkatan terakhir dapat digolongkan khusus dengan istilah “bernalar”, yang disebut juga dengan berpikir tingkat tinggi.

Guru harus mampu memilih model dan strategi pembelajaran yang sesuai dan dapat menunjang proses belajar mengajar matematika. Dari berbagai model pembelajaran yang berkembang saat ini diantaranya adalah *Means Ends Analysis*. Model *Means Ends Analysis* menyajikan langkah pembelajaran yang menuntut siswa berperan aktif dalam proses pembelajaran. dimulai dari membuat kelompok, mengarahkan siswa untuk mengidentifikasi masalah lalu merumuskan masalah dan menuntut penyelesaian yang tepat.

Menurut Herdian (2009) model pembelajaran *Means Ends Analysis* adalah terdiri dari tiga unsur kata yakni : *Mean*, *End* dan *Analysis*. *Mean* menurut bahasa yakni berarti, banyaknya cara. Sedangkan *End* adalah akhir atau tujuan, dan *Analysis* berarti analisa atau penyelidikan secara sistematis. *Means Ends Analysis* pertama kali diperkenalkan oleh Newell dan Simon (Wikipedia, 2007) dalam *General Problem Solving* (GPS), yang menyatakan bahwa *Means Ends Analysis* adalah suatu teknik pemecahan masalah di mana pernyataan sekarang dibandingkan dengan tujuan, dan perbedaan di antaranya

dibagi ke dalam sub-sub tujuan untuk memperoleh tujuan dengan menggunakan operator yang sesuai.

Beberapa penelitian yang berkaitan dengan model *Means Ends Analysis* menunjukkan hasil yang positif terhadap proses pembelajaran, yaitu penelitian yang dilakukan oleh Citroesmi dkk (2017) tentang penerapan model pembelajaran *Means Ends Analysis* untuk meningkatkan kemampuan pemecahan masalah matematis siswa, hasil penelitian ini menunjukkan bahwa penggunaan model *Means Ends Analysis* sangat tepat untuk meningkatkan kemampuan pemecahan masalah matematis siswa; Wahyono (2017) yang berjudul penerapan *model Means Ends Analysis* pada pembelajaran matematika materi ajar perbandingan, menyatakan penerapan model *Means Ends Analysis* pada materi ajar perbandingan dapat meningkatkan aktivitas belajar dan rasa percaya diri siswa.

Berpikir reflektif merupakan suatu kegiatan berpikir yang dapat membuat siswa berusaha menghubungkan pengetahuan yang diperolehnya untuk menyelesaikan permasalahan baru yang berkaitan dengan pengetahuan lamanya. Dalam pembelajaran matematika, kemampuan berpikir reflektif dikatakan penting, karena beberapa penelitian terdahulu oleh Noer (2010) sudah menunjukkan bahwa dengan strategi belajar yang menggunakan proses berpikir reflektif memberikan hasil yang lebih baik jika dibandingkan dengan siswa yang belajar dengan pembelajaran biasa. Sejalan dengan Choy (2012) menyatakan bahwa berpikir reflektif didefinisikan sebagai kesadaran tentang apa yang diketahui dan apa yang dibutuhkan, hal ini sangat penting untuk menjembatani kesenjangan situasi belajar.

Penelitian yang dilakukan oleh Sani (2016) tentang perbandingan kemampuan siswa berpikir reflektif dengan siswa berpikir intuitif di sekolah menengah atas, hasil penelitian ini menyatakan bahwa siswa berpikir reflektif menunjukkan hasil kemampuan pemecahan masalah dan prestasi belajar matematika lebih baik dari siswa berpikir intuitif.

Berdasarkan hasil wawancara dengan salah satu guru matematika di SMA Negeri 1 Gedongtataan, diketahui bahwa masih banyak siswa yang kesulitan dalam proses belajar matematika hal ini karena masih rendahnya kemampuan berpikir matematis siswa. Selain itu, siswa tidak mau berperan aktif dalam menggali informasi mengenai pembelajaran matematika, siswa cenderung hanya menunggu penyampaian dari guru sehingga menyebabkan masih rendahnya hasil belajar matematika pada siswa kelas XI.

Hasil pembelajaran matematika siswa kelas XI di SMA Negeri 1 Gedongtataan masih tergolong sangat rendah. Ini terbukti dari nilai semester genap 92 siswa kelas XI SMA Negeri 1 Gedongtataan mata pelajaran matematika tahun ajaran 2018/2019 persentase siswa tuntas di atas Kriteria Ketuntasan Minimal (KKM) sebesar 70 hanya sebesar 55% dari 100%. Terdapat beberapa faktor yang mempengaruhi kesulitan belajar matematika siswa, disebabkan karena kegiatan belajar mengajar dikelas hanya berfokus pada guru dan siswa pasif dalam belajar.

Berdasarkan permasalahan di atas, perlu dikembangkan model pembelajaran yang dapat membantu peserta didik dalam memahami konsep matematika sehingga dapat meningkatkan kemampuan berpikir reflektif matematis, dan juga model pembelajaran

yang dapat diterapkan oleh guru dengan mudah. Yaitu dengan penggunaan model pembelajaran *Means Ends Analysis* dalam pembelajaran matematika diharapkan dapat meningkatkan kemampuan berpikir reflektif siswa dalam belajar matematika, dan guru tidak lagi mengajar dengan monoton. Namun, berdasarkan Surat Edaran DEKAN FKIP Universitas Lampung tentang penyelesaian skripsi dan tesis mahasiswa di lingkungan FKIP Universitas Lampung. Nomor: 1980/UN26.13/PP.03.02/2020. Maka dalam rangka melaksanakan protokol Darurat Pencegahan Penyebaran infeksi covid-19. sehingga penelitian tidak perlu sampai pada uji efektivitas (yang memerlukan kelas untuk uji secara offline), namun cukup sampai uji ahli dan uji praktisi (guru dan siswa).

METODE PENELITIAN

Jenis pengembangan yang digunakan pada penelitian ini adalah *Research and Development (R&D)*. *Research & Development* adalah metode penelitian yang digunakan untuk menghasilkan produk tertentu, dan menguji keefektifan produk tersebut. Penelitian ini mengikuti alur Borg and Gall (1983, 777-794). Terdapat 10 langkah yaitu: *Research and Information Collecting* (melakukan penelitian dan pengumpulan informasi) pada tahap ini dilakukan wawancara dan observasi di SMA Negeri 1 Gedongtataan, *Planning* (melakukan perencanaan), *Develop Preliminary Form of Product* (mengembangkan bentuk awal produk), adapun pengembangan yang dilakukan pada penelitian ini adalah penambahan langkah pada model pembelajaran *Means Ends Analysis* yang bertujuan meningkatkan kemampuan berpikir reflektif dalam pembelajaran Matematika.

Preliminary Field Testing (melakukan uji lapangan awal) dilaksanakan pada siswa kelas XI IPA 1, *Main Product Revision* (melakukan revisi produk utama), *Main Field Testing* (melakukan uji lapangan untuk produk utama), *Operational Product Revision* (melakukan revisi produk operasional), *Operational Field Testing* (melakukan uji lapangan terhadap produk final), *Final product revision* (melakukan revisi produk final), dan *Dissemination and implementation* (diseminasi dan implementasi).

Indikator kemampuan reflektif menurut Noer (2010) yaitu *reacting* (bereaksi dengan permasalahan yang diberikan), *comparing* (mengevaluasi apa yang diyakini dengan membandingkan reaksi dan pengalaman yang lain), dan *contemplating* (menguraikan, menginformasikan, dan merekonstruksi permasalahan).

Teknik pengambilan data pada penelitian ini menggunakan nontes. Terdapat dua jenis instrumen nontes yang digunakan yaitu wawancara dan angket. Wawancara digunakan saat penelitian pendahuluan saat observasi pada studi pendahuluan, sedangkan angket digunakan saat penelitian penilaian perangkat pembelajaran dan model pembelajaran. Angket ini memakai skala likert dengan 4 pilihan jawaban.

Berikut uraian instrumen yang digunakan pada penelitian pengembangan ini angket validasi ahli: validasi pengembangan model pembelajaran MEA pada silabus, Rencana Pelaksanaan Pembelajaran (RPP), dan Lembar Kerja Kelompok (LKK).

Tabel 1.1 Interpretasi Kriteria Penilaian Validitas Instrumen

Persentase (%)	Kriteria Validasi
76-100	Valid
56-75	Cukup Valid
40-55	Kurang Valid
0-39	Tidak Valid

Angket tanggapan guru dan siswa terhadap model pembelajaran MEA. Hasil tanggapan guru dan respon siswa digunakan untuk mengetahui kepraktisan model pembelajaran MEA.

Tabel 1.2 Kriteria Kepraktisan Analisis Rata-rata

Nilai	Tingkat Kepraktisan
85-100	Sangat praktis
70-84	Praktis
55-69	Cukup Praktis
50-54	Kurang Praktis
0-49	Tidak Praktis

HASIL DAN PEMBAHASAN

Penelitian dilakukan di SMA Negeri 1 Gedongtataan Kabupaten Pesawaran. Menghasilkan produk berupa buku pengembangan model pembelajaran *Means Ends Analysis* (MEA), silabus, RPP, dan LKK. Yang bertujuan untuk mengetahui kepraktisan dan peningkatan kemampuan berpikir reflektif matematis siswa dari produk model pembelajaran *Means Ends Analysis*.

Tahapan pada penelitian ini diawali dengan melakukan observasi pada kelas XI, serta melakukan wawancara dengan guru yang mengajar matematika pada kelas XI. Pada tahap selanjutnya yaitu perencanaan pengembangan model *Means Ends Analysis* yang disusun berdasarkan kepada kebutuhan yang diperoleh dari hasil observasi dan wawancara.

Selanjutnya peneliti melakukan penyusunan dan pembuatan perangkat pembelajaran yang mengacu pada model *Means Ends Analysis*. Perangkat pembelajaran tersebut berupa Buku Model, RPP, Silabus serta LKK (lembar kerja kelompok), setelah itu buku model dan perangkat pembelajaran yang lain divalidasi oleh ahli dan diujicobakan.

2. Hasil Validasi Ahli

a. Validasi Pengembangan Model Pembelajaran *Means Ends Analysis* (MEA)

Validasi ahli pengembangan pembelajaran dilakukan oleh pihak yang berkompeten dalam bidang matematika maupun pendidikan matematika. Para ahli pengembangan pembelajaran ini adalah dosen jurusan pendidikan matematika FKIP Universitas Lampung, yaitu Bapak Dr. Sugeng Sutiarso, M.Pd. dan Dosen jurusan pendidikan matematika FKIP Universitas Islam Negeri Raden Intan, yaitu Bapak Dr. Bambang Sri Anggoro, M.Pd. Hasil penilaian ahli dapat dilihat pada Tabel 1.3.

Tabel 1.3 Penilaian Validasi Pengembangan Model oleh Ahli

No	Nama Validator	Skor	Skor Total	%	Kriteria Valid
1	Dr. Sugeng Sutiarto, M.Pd	49	52	94,23%	Valid
2	Dr. Bambang Sri Anggoro, M.Pd	51	52	98,07%	Valid

Berdasarkan tabel diatas diperoleh hasil validasi dari kedua ahli model pembelajaran memenuhi kriteria valid dimana bapak Dr. Sugeng Sutiarto, M.Pd memberikan skor 49 dengan persentase sebesar 94,23 % dan Bapak Dr. Bambang Sri Anggoro, M.Pd memberikan skor 51 dengan persentase sebesar 98,07 %. Proses selanjutnya adalah dilakukan uji *Q-chohran* untuk mengetahui keseragaman penilaian yang hasilnya validator memberikan pertimbangan yang sama. Berdasarkan uji *Q-chochran* yang telah dilakukan maka didapat nilai *Asymp.sig* adalah $0,157 > 0,05$ maka hipotesis H_0 diterima yang artinya tidak ada perbedaan antara validator 1 dan validator 2 dalam memberikan pertimbangan terkait desain pengembangan pembelajaran model *Means Ends Analysis* (MEA) yang dikembangkan. sehingga model pembelajaran dapat digunakan dalam peroses pembelajaran.

b. Validasi perangkat pembelajaran

Validasi yang terkait materi dan media pembelajaran dilakukan oleh pihak yang berkompeten dalam bidang matematika maupun pendidikan matematika. Validasi terhadap perangkat pembelajaran meliputi silabus, RPP dan LKK dilakukan oleh dua orang ahli materi, yakni dosen jurusan pendidikan matematika FKIP Universitas Lampung, yaitu Dr. Sugeng Sutiarto, M.Pd. Dosen jurusan pendidikan matematika FKIP Universitas Islam Negeri Raden Intan, yaitu Dr. Bambang Sri Anggoro, M.Pd. Hasil untuk penilaian silabus dari para ahli ahli disajikan pada Tabel 1.4.

Tabel 1.4 Penilaian Validasi Peragkat Pembelajaran Oleh Ahli

Jenis Angket	Nama Validator	Skor	Skor Total	%	Kriteria Valid
Silabus	Dr. Sugeng Sutiarto, M.Pd	33	40	82,50	Valid
	Dr. Bambang Sri Anggoro, M.Pd	39	40	97,50	Valid
RPP	Dr. Sugeng Sutiarto, M.Pd	38	48	79,17	Valid
	Dr. Bambang Sri Anggoro, M.Pd	44	48	91,67	Valid
LKK	Dr. Sugeng Sutiarto, M.Pd	80	96	83,33	Valid
	Dr. Bambang Sri Anggoro, M.Pd	83	96	86,46	Valid

Berdasarkan Tabel 1.4 diperoleh hasil validasi yaitu untuk silabus, RPP dan LKK pembelajaran dari kedua ahli materi memenuhi kriteria valid. Selanjutnya dilakukan uji *Q-chohran* untuk mengetahui keseragaman penilaian.

Berdasarkan uji *Q-chochran* yang telah dilakukan terkait Silabus dan RPP maka didapat nilai *Asymp.sig* adalah $0,034 > 0,05$ terkait LKK didapat nilai *Asymp.sig* adalah $0,317 > 0,05$ maka dapat disimpulkan bahwa hipotesis H_0 diterima yang artinya tidak ada perbedaan antara validator 1 dan validator 2 dalam memberikan pertimbangan

terkait Silabus, RPP dan LKK, sehingga perangkat pembelajaran yang dikembangkan dapat digunakan pada proses pembelajaran.

c. Validasi Tes Kemampuan Berpikir Reflektif Matematis

Validasi instrumen tes keterampilan berpikir reflektif dalam penelitian ini dilakukan oleh dua orang ahli materi yakni dosen jurusan pendidikan matematika FKIP Universitas Lampung yaitu Dr. Sugeng Sutiarto, M.Pd. Dosen jurusan pendidikan matematika FKIP Universitas Islam Negeri Raden Intan yaitu Dr. Bambang Sri Anggoro, M.Pd. Hasil penilaian ahli materi tentang tes kemampuan berpikir reflektif matematis disajikan pada Tabel 1.5.

Tabel 1.5 Penilaian Validasi Instrumen Tes Kemampuan Berpikir Reflektif Matematis

Ahli	Skor	%	Kriteria Valid
Dr. Sugeng Sutiarto, M.Pd	38	79,17%	Valid
Dr. Bambang Sri Anggoro, M.Pd	45	93,75%	Valid

Berdasarkan tabel diatas diperoleh hasil validasi dari kedua ahli model pembelajaran memenuhi kriteria valid. Selanjutnya dilakukan uji *Q-chohran* untuk mengetahui keseragaman penilaian.

Berdasarkan uji *Q-chochran* yang telah dilakukan maka didapat nilai *Asymp.sig* adalah $0,020 > 0,05$ maka hipotesis H_0 diterima yang artinya tidak ada perbedaan antara validator 1 dan validator 2 dalam memberikan pertimbangan terkait instrumen tes kemampuan berpikir reflektif matematis yang dikembangkan. sehingga model pembelajaran dapat digunakan dalam proses pembelajaran.

Langkah penelitian selanjutnya adalah uji coba lapangan awal dilakukan dengan tujuan untuk mengetahui tingkat kemenarikan dan kejelasan model terhadap model pembelajaran *Means Ends Analysis* (MEA). Pengambilan data dilakukan dengan simulasi terhadap model pembelajaran *Means Ends Analysis* (MEA). Peneliti juga memberikan angket tanggapan guru matematika terhadap model pembelajaran *Means Ends Analysis* (MEA) dan perangkat pembelajarannya.

a. Angket Tanggapan Guru Matematika

1. Angket Taggapan Guru Matematika Terhadap Model Pembelajaran *Means Ends Analysis* (MEA)

Komponen yang dinilai dalam tahap ini adalah tanggapan guru matematika terhadap model pembelajaran *Means Ends Analysis* (MEA). Aspek dan skala tanggapan guru matematika dapat dilihat pada rekapitulasi perolehan skor tanggapan guru pada

Tabel 1.6 Rekapitulasi Angket Tanggapan Guru terhadap Model *Means Ends Analysis* (MEA)

Guru	Komponen	Total	Kategori
May Eri Budiono, S.Pd	Aspek Petunjuk	8	Baik
	Aspek Cakupan	34	
	Aspek Bahasa	8	
Istasari Syaifatunnisa, S.Pd	Aspek Petunjuk	8	
	Aspek Cakupan	32	
	Aspek Bahasa	6	

Berdasarkan Tabel 1.6, penilaian dari penilaian dua guru tersebut diperoleh kepraktisan model pembelajaran *Means Ends Analysis* (MEA) yang dikembangkan dengan kategori baik.

2. Angket Tanggapan Guru Matematika terhadap Silabus

Komponen yang dinilai dalam tahapan ini adalah angket Tanggapan Guru Matematika terhadap Silabus yaitu kesesuaian format silabus dan teknik penilaian. Instrumen yang digunakan berupa skala respon. Kisi – kisi dan skala tanggapan Guru Matematika dapat dilihat pada rekapitulasi perolehan skor skala siswa untuk uji coba lapangan awal yang dijelaskan pada Tabel 1.7

Tabel 1.7 Rekapitulasi Angket Tanggapan Guru Matematika terhadap Silabus

Guru	Komponen	Total	Kategori
May Eri Budiono, S.Pd	Kesesuaian Format Silabus	23	Baik
	Teknik Penilaian	8	
	Kesesuaian Format Silabus	20	
Istasari Syaifatunnisa, S.Pd	Teknik Penilaian	7	

Berdasarkan Tabel 1.7, penilaian dari dua orang guru tersebut adalah bahwa kepraktisan silabus model pembelajaran *Means Ends Analysis* (MEA) yang dikembangkan dengan kategori baik.

3. Angket Tanggapan Guru Matematika terhadap RPP

komponen yang dinilai dalam tahapan ini adalah angket tanggapan guru matematika terhadap RPP. Kisi -kisi dan skala tanggapan guru matematika dapat di lihat pada rekapitulasi perolehan skor uji coba lapangan awal pada Tabel 1.8.

Tabel 1.8 Rekapitulasi Angket Tanggapan Guru Matematika terhadap RPP

Guru	Komponen	Total	Kategori
May Eri Budiono, S.Pd	Identitas Mata Pelajaran	7	Baik
	Rumusan Tujuan/Indikator	16	
	Materi	10	
	Metode Pembelajaran	12	
	Kegiatan Pembelajaran	10	
	Pemilihan Media/Sumber Belajar	11	
	Penilaian Hasil Belajar	14	
	Kebahasaan	10	
	Pengembangan Karakter	8	
	Identitas Mata Pelajaran	8	
Istasari Syaifatunnisa, S.Pd	Rumusan Tujuan/Indikator	14	
	Materi	10	
	Metode Pembelajaran	10	
	Kegiatan Pembelajaran	12	
	Pemilihan Media/Sumber Belajar	12	
	Penilaian Hasil Belajar	12	
	Kebahasaan	9	
	Pengembangan Karakter	8	

Berdasarkan dari Tabel 1.8, penilaian dari dua orang guru tersebut menunjukkan RPP dengan model pembelajaran *Means Ends Analysis* (MEA) memperoleh nilai kepraktisan dengan kategori baik.

4. Angket Tanggapan Guru terhadap LKK

Pada tahapan ini komponen yang dinilai adalah angket tanggapan guru matematika terhadap LKK. Aspek dan skala tanggapan guru matematika dapat dilihat pada rekapitulasi perolehan skor tanggapan guru pada Tabel 1.9.

Tabel 1.9 Rekapitulasi Angket Respon Guru Matematika Terhadap LKK

Guru	Komponen	Total	Kategori
May Eri Budiono, S.Pd	Syarat Didaktik	51	Baik
	Syarat Teknik	11	
	Syarat Konstruksi	12	
	Syarat Lain	16	
	Syarat Didaktik	48	
Istasari Syaifatunnisa, S.Pd	Syarat Teknik	9	
	Syarat Konstruksi	10	
	Syarat Lain	16	

Berdasarkan dari Tabel 1.9, penilaian dari dua guru tersebut bahwa kepraktisan LKK model pembelajaran *Means Ends Analysis* (MEA) yang dikembangkan dengan kategori baik.

b. Angket Respon Siswa

Kisi-kisi dan skala respon siswa terhadap LKK dapat di lihat pada perolehan skor skala siswa untuk ujicoba lapangan awal yang dilihat pada Tabel 1.10.

Tabel 1.10 Rekapitulasi Angket Respon Siswa terhadap LKK

No	Komponen	Jumlah Total	Jumlah Skor Ideal	Kategori Penilaian
1.	Tampilan LKK	132	144	Baik
2.	Penyajian Materi	161	192	
3.	Manfaat LKK	64	72	

Berdasarkan Tabel 1.10 pada tampilan LKK memperoleh jumlah skor 132 dari skor ideal 144 yang artinya bahwa kepraktisan LKK berbasis model *Means Ends Analysis* (MEA) yang dikembangkan dalam kategori baik.

Pengembangan model pembelajaran *Means Ends Analysis* (MEA) terbukti praktis dalam meningkatkan kemampuan berpikir reflektif matematis siswa berdasarkan faktor-faktor yaitu, faktor pertama dirumuskan perencanaan program pembelajaran atau yang sering disebut perangkat pembelajaran yang telah diuji validitas dan kepraktisannya. Kemudian faktor kedua terdapat kesesuaian antara perangkat yang dikembangkan dengan langkah pembelajaran *Means Ends Analysis* (MEA) yaitu pada tahap ke 4 dimana siswa bersama-sama dalam kelompoknya untuk mengidentifikasi masalah, menyederhanakan masalah hingga menarik kesimpulan dan menyajikan masalah melalui persentasi didepan kelas.

Berdasarkan faktor-faktor yang diuraikan di atas maka diperoleh bahwa, pengembangan model pembelajaran *Means Ends Analysis* (MEA) lebih praktis dalam meningkatkan kemampuan berpikir reflektif matematis siswa, sehingga siswa terbiasa untuk menggunakan skill berpikir reflektif tingkat tinggi khususnya kemampuan berpikir reflektif matematis.

KESIMPULAN DAN SARAN

Berdasarkan hasil penelitian dan pembahasan, diperoleh kesimpulan bahwa Pengembangan model *Means Ends Analysis* (MEA) untuk meningkatkan kemampuan berpikir reflektif matematis siswa, dilakukan melalui analisis studi pendahuluan, pengembangan produk, validasi ahli, uji coba lapangan awal, dan uji coba lapangan. Produk pengembangan model *Means Ends Analysis* (MEA) untuk meningkatkan kemampuan berpikir reflektif matematis siswa layak untuk diimplementasikan setelah memenuhi kriteria valid dan praktis.

Saran untuk penelitian selanjutnya yaitu dapat mengembangkan penelitian lanjutan mengenai model pembelajaran *Means Ends Analysis* (MEA) pada materi yang lain sehingga produk yang dihasilkan dapat digunakan pada semua materi pembelajaran matematika, pada tingkat satuan pendidikan yang berbeda atau kemampuan yang difasilitasi berbeda.

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THE FORMULA TO COUNT THE NUMBER OF VERTICES LABELED ORDER SIXCONNECTED GRAPHS WITH MAXIMUM THIRTY EDGES WITHOUT LOOPS

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Abstract

If for every pair of vertices in a graph $G(V,E)$ there exist minimum one path joining them, then G is called connected, otherwise the graph is called disconnected. If n vertices and m edges are given then numerous graphs are able to be created. The graphs created might be disconnected or connected, and also maybe simple or not. A simple graph is a graph whose no parallel edges nor loops. A loop is an edges that connects the same vertex while parallel edges are edges that connecting the same pair of vertices. In this research we will discuss the formula to count the number of connected vertex labeled order six graph containing at most thirty edges and may contain fifteen parallel edges without loops.

Keywords: connected graph, vertices labeled, order six, loopless, parallel edges

1. Introduction

Nowadays, graph theory emerges as one of the active branches in mathematics. That condition cannot be separated from the role of graph theory in daily-life. The flexibility representation of a graph can be adopted to represent many real-life problems fuels graph theory to lead this branch. By using graph theory, we can visualize real-problem easily. A point $v_i \in V$ in graph can represent an object such as a city, an airport, a depot, a train station, a computer, and so on, while an edge $e_{ij} \in E$ of a graph which connects a pair v_i, v_j of vertices in V can represent a road, a train track, and so on. There fore, given a graph $G(V,E)$ where $V \subseteq \mathbb{R}$, $V = \{v_1, v_2, \dots, v_n\}$, and $E = \{e_{ij} \mid v_i, v_j \in V\}$. a graph V can. for example. represent computer networks where the points in

V represent the computers, and the edges in E represent the cable or transmission line in the system. The flexibility of the graph occurs because of the way of drawing the graph itself.

No one can claim that his way of drawing a graph is the only single correct way [1]. The application of graph theory appear in many fields such as in biology, chemistry, agriculture, medicine, engineering, and so on. In biology, for example, the used of graph theory in biological network is explored [2], in representing DNA and phylogeny [3-4], in agriculture [5], in psychology [6], etc. The rest of this article will contain literature review in Section 2, graphs observation and construction is given in Section 3, results and discussion will be provided in Section 4, and the conclusion is given in Section 5.



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2. Literature Review

The history of graph enumeration was laid back in 1874 when Cayley found relationship with graph theory when he calculated the number of hydrocarbons C_nH_{2n+2} isomers. Cayley found that counting the number of isomers is related to rooted tree enumeration [7]. [7]. In 1964, Slomenski used the graph concepts to observed the hydrocarbon's additive structural properties [8]. Given n number of vertices and m number of edges, numerous graphs can be created. A simple graph is a graph whose no loops nor parallel edges. In 2007 Bóna gave the method to enumerate forests and trees [9], and Stanley provides the use of generating function for enumeration [10-11]. How to count the number of disconnected vertices labeled of order maximum of four graphs is observed in [12]. The number of disconnected vertices labeled order five graphs containing no parallel edges also observed in [13], and in 2019 the formula to count the number of connected vertices labeled order five graphs with maximum five parallel edges is proposed in [14].

3. Graphs Observation and Construction

Given $n = 6$ and $5 \leq m \leq 30$, numerous graphs can be created. Among those graphs that can be formed, we restrict and only take into account connected graphs with $6 \leq t \leq 15$, where t is the number of edges that connect different pair of vertices. Moreover, after doing that sorting, we count isomorphic graphs as one graph. The following figures show some patterns of the graphs that can be formed, and due to limited space, we only display some patterns here.

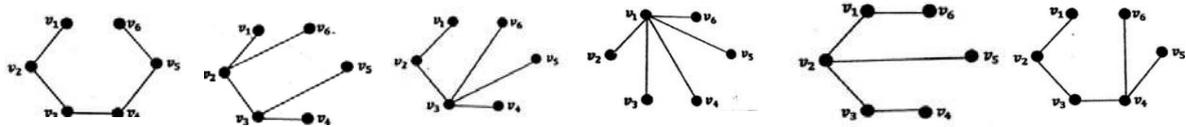


Figure 1. Some patterns obtained for $m = 5$ and $t = 5$



Figure 2. Some patterns obtained for $m = 6$, $t = 5$

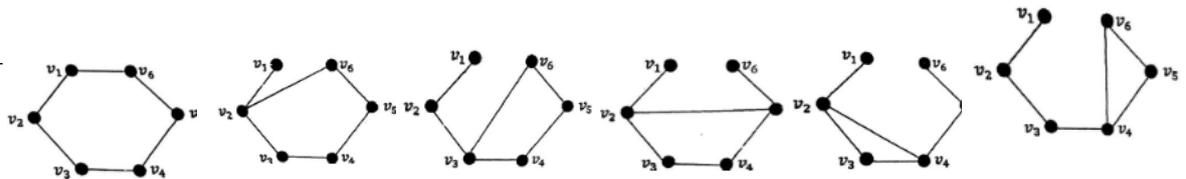


Figure 3. Some patterns obtained for $m = 6$, $t = 6$

4. Results and Discussion

From the process observation and construction, the graphs obtained are grouped into m and t , where t is the number of edges connecting different pairs of vertices in graph. Note that parallel edges are not contributes to t , i.e. parallel edges are conted as one. By that procedure we get Table 1.

Table 1. The number of connected vertices labeled order six graphs with maximum thirty edges and may contain fifteen parallel edges, without loops.

m	t															
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
5	1296															
6	6480	1980														
7	19440	11880	3330													
8	45360	41580	23310	4620												
9	90720	110880	93240	36960	6660											
10	163296	249480	279720	166320	59940	2460										
11	272160	498960	699300	554400	299700	24600	1155									
12	427680	914760	1538460	1524600	1098900	135300	12705	420								
13	641520	1568160	3076920	3659040	3296700	541200	76230	5040	150							
14	926640	2548260	5714280	7927920	8571420	1758900	330330	32760	1950	15						
15	1297296	3963960	9999990	15855840	19999980	4924920	1156155	152880	13650	210	1					
16	1769040	5945940	16666650	29729700	42857100	12312300	3468465	573300	68250	1575	15					
17	2358720	8648640	26666640	52852800	85714200	28142400	9249240	1834560	273000	8400	120					
18	3084480	12252240	41212080	89849760	161904600	59802600	22462440	5197920	928200	35700	680					
19	3965760	16964640	61818120	147026880	291428280	119605200	50540490	13366080	2784600	128520	3060					
20	5023296	23023440	90349560	232792560	503376120	227249880	106696590	31744440	7558200	406980	11628					
21	6279120	30697920	129070800	358142400	838960200	413181600	213393180	70543200	18895500	1162800	38760					
22	40291020	180699120	537213600	1355243400	723067800	407386980	148140720	44089500	3052350	116280						
23	248461290	787913280	2129668200	1223653200	746876130	296281440	96996900	7461300	319770							
24	1132625340	3265491240	2010287400	1321396230	567872760	202811700	17160990	817190								
25	4898236860	3216459840	2265250680	1048380480	405623400	37442160	1961256									
26	5025718500	5025718500	3775417800	1872108000	780045000	156009000	9657700									
27	6135053925	6135053925	3244987200	1448655000	260759000	300874500										
28	4563263250	4563263250	5475915900	20058300	40116600											
29	1017958725	1017958725	77558760													
30																

By analyzing the numbers in every column, we can derive Table 2 as follows:

Table 2. An alternative form of Table 1

The number of connected vertices labeled order six graphs with thirty edges and may contained fifteen parallel edges, without loops

m	5	6	7	8	9	10	11	12	13	14	15
5	1 x 1296										
6	5 x 1296	1 x 1980									
7	15 x 1296	6 x 1980	1 x 3330								
8	35 x 1296	21 x 1980	7 x 3330	1 x 4620							
9	70 x 1296	56 x 1980	28 x 3330	8 x 4620	1 x 6660						
10	126 x 1296	126 x 1980	84 x 3330	36 x 4620	9 x 6660	1 x 2460					
11	210 x 1296	252 x 1980	210 x 3330	120 x 4620	45 x 6660	10 x 2460	1 x 1155				
12	330 x 1296	462 x 1980	462 x 3330	330 x 4620	165 x 6660	55 x 2460	11 x 1155	1 x 420			
13	495 x 1296	792 x 1980	924 x 3330	792 x 4620	495 x 6660	220 x 2460	66 x 1155	12 x 420	1 x 150		

14	715 x 1296	1287 x 1980	1716 x 3330	1716 x 4620	1287 x 6660	715 x 2460	286 x 1155	78 x 420	13 x 150	1 x 15
15	1001 x 1296	2002 x 1980	3003 x 3330	3432 x 4620	3003 x 6660	2002 x 2460	1001 x 1155	364 x 420	91 x 150	14 x 15
16	1365 x 1296	3003 x 1980	5005 x 3330	6435 x 4620	6435 x 6660	5005 x 2460	3003 x 1155	1365 x 420	455 x 150	105 x 15
17	1820 x 1296	4368 x 1980	8008 x 3330	11440 x 4620	12870 x 6660	11440 x 2460	8008 x 1155	4368 x 420	1820 x 150	560 x 15
18	2380 x 1296	6188 x 1980	12376 x 3330	19448 x 4620	24310 x 6660	24310 x 2460	19448 x 1155	12376 x 420	6188 x 150	2380 x 15
19	3060 x 1296	8568 x 1980	18564 x 3330	31824 x 4620	43758 x 6660	48620 x 2460	43758 x 1155	31824 x 420	18564 x 150	8568 x 15
20	3876 x 1296	11628 x 1980	27132 x 3330	50388 x 4620	75582 x 6660	92378 x 2460	92378 x 1155	75582 x 420	50388 x 150	27132 x 15
21	4845 x 1296	15504 x 1980	38760 x 3330	77520 x 4620	125970 x 6660	167960 x 2460	184756 x 1155	167960 x 420	125970 x 150	77520 x 15
22	5985 x 1296	20349 x 1980	54264 x 3330	116280 x 4620	203490 x 6660	293930 x 2460	352716 x 1155	352716 x 420	293930 x 150	203490 x 15
23		26334 x 1980	74613 x 3330	170544 x 4620	319770 x 6660	497420 x 2460	646646 x 1155	705432 x 420	646646 x 150	497420 x 15
24			100947 x 3330	245157 x 4620	490314 x 6660	817190 x 2460	1144066 x 1155	1352078 x 420	1352078 x 150	1144066 x 15
25				346104 x 4620	735471 x 6660	1307504 x 2460	1961256 x 1155	2496144 x 420	2704156 x 150	2496144 x 15
26					1081575 x 6660	2042975 x 2460	3268760 x 1155	4457400 x 420	5200300 x 150	5200300 x 15
27							5311735 x 1155	7726160 x 420	9657700 x 150	10400600 x 15
28								13037895 x 420	17383860 x 150	20058300 x 15
29									30421755 x 150	37442160 x 15
30										67863915 x 15
										77558760 x 1

By observing Table 2, we find that every column can be written as a product of a sequence of number that multiplied with a constant. The sequence of numbers for example in column 1 is : 1, 5, 15, 35, 70, 126, 210, 330, 495, 715, 1001, 1365, 1820, 2380, 3060, 3876, 4845, 5985 and those numbers are multiple by 1296 to get the same value that displayed in Table 1.

Notate that $G(p)_{n,m,t}$ as a connected loopless graph of order n with m edges which may contained parallel edges and t number of edges that connect different pair of vertices, $N(G(p)_{n,m,t})$ as the number of $G(p)_{n,m,t}$. $N(G(p)_{n,m,t}) = \square G(p)_{n,m,t} \square$.

Result 1 : Given n vertices ($n=6$), m , t edges, $5 \leq m \leq 30$, $t = 5$, t is the number of edges that connect different pair of points, then the number of connected vertices labeled loopless order six graphs with maximum fifteen parallel edges is $N(G(p)_{6,m,5}) = 1296 \times C^{(m-1)}$

Proof : The sequence that appears in the first column is: 1, 5, 15, 35, 70, 126, 210, 330, 495, 715, 1001, 1365, 1820, 2380, 3060, 3876, 4845, 5985

1	5	15	35	70	126	...	1820	2380	3060	3876	4845	5985
	4	10	20	35	56	...	560	680	816	969	1140	
		6	10	15	21	...	120	136	153	171		
			4	5	6	...	16	17	18			
				1	1	...		1	1			

Notice that the fixed difference appears on the fourth level. The related polynomial that can represent that sequence is order four polynomial: $P_4(m) = A_4m^4 + A_3m^3 + A_2m^2 + A_1m + A_0$
Using the value obtained in the first column we get:

$$\begin{aligned}
 1296 &= 625a_4 + 125a_3 + 25a_2 + 5a_1 + a_0 & (1) \\
 6480 &= 1296a_4 + 216a_3 + 36a_2 + 6a_1 + a_0 & (2) \\
 19440 &= 2401a_4 + 343a_3 + 49a_2 + 7a_1 + a_0 & (3) \\
 45360 &= 4096a_4 + 512a_3 + 64a_2 + 8a_1 + a_0 & (4) \\
 90720 &= 6561a_4 + 729a_3 + 81a_2 + 9a_1 + a_0 & (5)
 \end{aligned}$$

Equations (1) - (5) constitute a system of linear equations which can be represented by matrix

$Ax = b$, as follows:

$$\begin{bmatrix} 625 & 125 & 25 & 5 & 1 \\ 1296 & 216 & 36 & 6 & 1 \\ 2401 & 343 & 49 & 7 & 1 \\ 4096 & 512 & 64 & 8 & 1 \\ 6561 & 729 & 81 & 9 & 1 \end{bmatrix} \begin{bmatrix} a_4 \\ a_3 \\ a_2 \\ a_1 \\ a_0 \end{bmatrix} = \begin{bmatrix} 1296 \\ 6480 \\ 19440 \\ 45360 \\ 90720 \end{bmatrix}$$

Solving that matrix we get: $a_4 = \frac{1296}{24}$, $a_3 = -\frac{12960}{24}$, $a_2 = \frac{45360}{24}$, $a_1 = -\frac{64800}{24}$, and $a_0 = \frac{31104}{24}$

$$\begin{aligned} \text{Therefore : } P_4(m) &= \frac{1296}{24} m^4 - \frac{12960}{24} m^3 + \frac{45360}{24} m^2 - \frac{64800}{24} m + \frac{31104}{24} \\ &= \frac{1296}{24} \times (m^4 - 10m^3 + 35m^2 - 50m + 240) \\ &= \frac{1296}{24} \times ((m-1)(m-2)(m-3)(m-4)) \\ &= 1296 \times \frac{((m-1)(m-2)(m-3)(m-4))}{4 \times 3 \times 2 \times 1} \\ &= 1296 \times C_4^{(m-1)} \end{aligned}$$

Result 2 : Given n vertices ($n = 6$), and m, t , edges; $6 \leq m \leq 30$, $t = 6$, t is the number of edges connecting different pair of points/vertices (parallel edges are counted as one), then the number of connected verticed labeled loopless graphs of order six with maximum fifteen parallel edges is

$$N(G(p)6,m,6) = 1980 \times C^{(m-1)}$$

Proof :

The sequence that appears in the first column is: 1, 6, 21, 56, 126, 252, 462, 792, 1287, 2002, 3003, 4368, 6188, 8568, 11628, 15504, 20349, 26334.

1	6	21	56	126	252	462	...	4368	6188	8568	11628	15504	20349	26334
	5	15	35	70	126	210	...	1820	2380	3060	3876	4845	5985	
		10	20	35	56	84	...	560	680	816	969	1140		
			10	15	21	28	...	120	136	153	171			
				5	6	7	...	16	17	18				
					1	1	...	1	1					

Notice that the fixed difference appears on the fifth level. The related polynomial that can represent that sequence is order five polynomial: $Q_5(m) =$

$$A_5m^5 + A_4m^4 + A_3m^3 + A_2m^2 + A_1m + A_0$$

Using the value obtained in the first column we get:

$$1980 = 7776a_5 + 1296a_4 + 216a_3 + 36a_2 + 6a_1 + a_0 \tag{6}$$

$$11880 = 16807a_5 + 2401a_4 + 343a_3 + 49a_2 + 7a_1 + a_0 \tag{7}$$

$$41580 = 32768a_5 + 4096a_4 + 512a_3 + 64a_2 + 8a_1 + a_0 \tag{8}$$

$$110880 = 59049a_5 + 6561a_4 + 729a_3 + 81a_2 + 9a_1 + a_0 \tag{9}$$

$$249480 = 100000a_5 + 10000a_4 + 1000a_3 + 100a_2 + 10a_1 + a_0 \tag{10}$$

$$498960 = 161051a_5 + 14641a_4 + 1331a_3 + 121a_2 + 11a_1 + a_0 \tag{11}$$

By solving that system of equations we get:

$$a_5 = \frac{1980}{120}, a_4 = -\frac{29700}{120}, a_3 = \frac{168300}{120}, a_2 = -\frac{445500}{120}, a_1 = \frac{542520}{120}, a_0 = -\frac{232600}{120}$$

$$\begin{aligned}
 \text{Therefore } Q_5(m) &= \frac{1980}{1980}m^5 - \frac{29700}{120}m^4 + \frac{168300}{120}m^3 - \frac{445500}{120}m^2 + \frac{542520}{120} - \frac{232600}{120} \\
 &= \frac{120}{1980}(m^5 - 15m^4 + 85m^3 - 225m^2 + 274m - 120) \\
 &= \frac{1980}{120}((m-1)(m-2)(m-3)(m-4)(m-5)) \\
 &= 1980 \times \frac{(m-1)(m-2)(m-3)(m-4)(m-5)}{5 \times 4 \times 3 \times 2 \times 1} \\
 &= 1980 \times C_5^{(m-1)}
 \end{aligned}$$

Observing and continuing by this manner we get:

- Result 3:** Given n vertices (n = 6), and m, t edges; $7 \leq m \leq 30, t = 7$ then $N(G(p)_{6,m,7}) = 3330 \times C_7^{(m-1)}$
- Result 4:** Given n vertices (n = 6), and m, t edges ; $8 \leq m \leq 30, t = 8$, then $N(G(p)_{6,m,8}) = 4620 \times C_8^{(m-1)}$
- Result 5 :** Given n vertices (n = 6), and m, t edges ; $9 \leq m \leq 30, t = 9$, then $N(G(p)_{6,m,9}) = 6660 \times C_9^{(m-1)}$
- Result 6:** Given n vertices (n = 6), and m, t edges; $10 \leq m \leq 30, t=10$, then $N(G(p)_{6,m,10}) = 2460 \times C_{10}^{(m-1)}$
- Result 7:** Given n vertices (n = 6), and m, t edges, $11 \leq m \leq 30, t=11$, then $N(G(p)_{6,m,11}) = 1155 \times C_{11}^{(m-1)}$
- Result 8:** Given n vertices (n = 6), and m, t edges, $12 \leq m \leq 30, t = 12$, then $N(G(p)_{6,m,12}) = 420 \times C_{12}^{(m-1)}$
- Result 9 :** Given n vertices (n = 6), and m, t edges, $13 \leq m \leq 30, t = 13$, then $N(G(p)_{6,m,13}) = 150 \times C_{13}^{(m-1)}$
- Result 10:** Given n vertices (n = 6), and m, t edges, $14 \leq m \leq 30, t = 14$, then $N(G(p)_{6,m,14}) = 15 \times C_{14}^{(m-1)}$
- Result 11:** Given n vertices (n = 6), and m, t edges, $15 \leq m \leq 30, t = 15$, then $N(G(p)_{6,m,15}) = C_{15}^{(m-1)}$

5. Conclusion

From the above discussion we are able to conclude that if given n vertices (n = 6), and m, t, edges; $5 \leq m \leq 30, t \leq m, 5 \leq t \leq 15, t$ is the number of edges connecting different pair vertices (parallel edges are counted as one), then the number of connected vertices labeled loop-lees order six graphs with maximum thirty edges and may contain at most fifteen parallel edges $N(G(p)_{6,m,t})$ is:

$$N(G(p)_{6,m,t}) = \sum_{t=5}^{15} N(G(p)_{6,m,t}), \text{ where } N(G(p)_{6,m,5}) = 1296 \times C_5^{(m-1)}, N(G(p)_{6,m,6}) = 1980 \times C_6^{(m-1)}, N(G(p)_{6,m,7}) = 3330 \times C_7^{(m-1)}, N(G(p)_{6,m,8}) = 4620 \times C_8^{(m-1)}, N(G(p)_{6,m,9}) = 6660 \times C_9^{(m-1)}, N(G(p)_{6,m,10}) = 2460 \times C_{10}^{(m-1)}, N(G(p)_{6,m,11}) = 1155 \times C_{11}^{(m-1)}, N(G(p)_{6,m,12}) = 420 \times C_{12}^{(m-1)}, N(G(p)_{6,m,13}) = 150 \times C_{13}^{(m-1)}, N(G(p)_{6,m,14}) = 15 \times C_{14}^{(m-1)}, N(G(p)_{6,m,15}) = C_{15}^{(m-1)}$$

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PENGARUH ETHANOLAMINA TERHADAP PEMBENTUKAN FASA, UKURAN PARTIKEL, DAN LUAS PERMUKAAN SPESIFIK NANOTITANIA MENGGUNAKAN METODE SOL GEL

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Abstract

Nanotitania has been prepared by sol gel method using ethanolamine as surfactant. This research was conducted to determine the effect of ethanolamine on the phase formation, particle size and surface area of TiO₂. In this study Ti-butoxide was used as a precursor and ethanol as a solvent, and then HCl. The amount of ethanolamine was varied to 0; 0.5; 1; 1.5; and 2 ml. The samples were calcined at a temperature of 500°C for 4 hours. TiO₂ was characterized using X-Ray Diffraction (XRD), Transmission Electron Microscopy (TEM), and Surface Area Analyzer (SAA) with BET method. The results of XRD characterization showed that in samples A-0.0 and A-0.5 an anatase phase was formed, whereas in the sample A-1.0 and A-1.5 an anatase, brookite, and rutile phases were formed with a weight percentage of 57,65 ± 1,6% wt; 27,06 ± 1,8% wt, and 15,29 ± 0,4% wt. Meanwhile, for sample A-1.5 it is 69,96 ± 1.6% wt, 24,52 ± 1,5% wt, and 5,52 ± 0,3% wt. Sample A-2.0 only produced anatase and brookite phases with weight percentages of 78,53 ± 1.5% wt and 21,47 ± 1.5% wt. The results of TEM characterization using ImageJ software show that the TiO₂ particle size in sample A-1.0 was 15,8 ± 1,0 nm. The results of the analysis surface area of sample A-1, produced the largest specific surface area, that is 172 m²/g, the smallest specific surface area was produced in sample A-1.5 that is 72,07 m²/g.

Keywords: nanotitania, ethanolamine, anatase, rutile, brookite.

Abstrak

Nanotitania telah dipreparasi dengan metode sol gel menggunakan ethanolamina sebagai surfaktan. Penelitian ini dilakukan untuk mengetahui pengaruh ethanolamina terhadap pembentukan fasa, ukuran partikel, dan luas permukaan TiO₂. Dalam penelitian ini Ti-butoksida dipakai sebagai prekursor dan etanol sebagai pelarut, kemudian HCl. Jumlah ethanolamina yang divariasikan adalah 0; 0.5; 1; 1.5; dan 2 ml. Sampel di kalsinasi pada suhu 500°C selama 4 jam. TiO₂ dikarakterisasi menggunakan X-

Ray Diffraction (XRD), Transmission Electron Microscopy (TEM), dan Surface Area Analyzer (SAA) dengan metode BET. Hasil karakterisasi XRD menunjukkan bahwa pada sampel A-0,0 dan A-0,5 terbentuk fasa anatase, sedangkan pada sampel A-1,0 dan A-1,5 terbentuk fasa anatase, brookite, dan rutile dengan presentase berat masing-masing $57,65 \pm 1,6$ %wt; $27,06 \pm 1,8$ %wt, dan $15,29 \pm 0,4$ %wt. Sedangkan untuk sampel A-1,5 sebesar $69,96 \pm 1,6$ %wt; $24,52 \pm 1,5$ %wt, dan $5,52 \pm 0,3$ %wt. Sampel A-2,0 hanya menghasilkan fasa anatase dan brookite saja dengan presentase berat masing-masing $78,53 \pm 1,5$ %wt dan $21,47 \pm 1,5$ %wt. Hasil karakterisasi TEM dengan menggunakan perangkat lunak ImageJ menunjukkan bahwa ukuran partikel TiO₂ pada sampel A-1,0 adalah $15,8 \pm 1,0$ nm. Hasil analisis luas permukaan spesifik sampel A-1,0 menghasilkan luas permukaan spesifik terbesar yaitu 172 m²/g, luas permukaan spesifik terkecil dihasilkan pada sampel A-1,5 yaitu $72,07$ m²/g.

Kata kunci: nanotitania, ethanolamina, anatase, rutile, brookite.

PENDAHULUAN

Akhir-akhir ini, nanoteknologi menjadi salah satu teknologi yang berkembang pesat dan berkontribusi besar pada perkembangan sains material [1]. Jenis nanoteknologi yang sedang dikembangkan adalah nanomaterial. Nanomaterial memiliki sifat elektrik yang besar, luas permukaan yang luas, sifat mekanik, optik dan kemagnetan yang lebih tinggi dibandingkan pada saat berbentuk limpahan (*bulk*) [2].

Bahan nanomaterial yang sedang dikembangkan dan diaplikasikan adalah titanium dioksida (TiO₂) atau titania sebagai material alternatif dalam berbagai aspek, terutama berkaitan dengan ukuran partikelnya. Semakin kecil partikelnya, maka semakin luas permukaan yang aktif untuk bereaksi sehingga semakin beragam potensi penerapannya [3]. TiO₂ banyak dimanfaatkan antara lain untuk dijadikan sensor, salah satunya sensor gas [4], dan TiO₂ paling banyak dimanfaatkan sebagai fotokatalis [5][6].

Secara struktur TiO₂ memiliki tiga bentuk polimorf yaitu anatase, rutile, dan brookite. Anatase dan rutile memiliki struktur kristal tetragonal, sedangkan brookite memiliki struktur kristal orthorombik. Fasa anatase dan brookite merupakan fasa metastabil yang mudah berubah menjadi fasa rutil ketika dipanaskan [7].

Ada dua metode sintesis TiO₂ yaitu metode fisik dan metode kimia. Kedua metode tersebut memiliki kekurangan dan kelebihan masing-masing. Metode fisika menghasilkan material dalam jumlah besar, tetapi ukurannya tidak memadai untuk nanometer. Sedangkan metode kimia dapat dibuat sampai ukuran nanometer [8]. Sampai saat ini, struktur nano TiO₂ telah diperoleh dengan metode yang berbeda seperti hidrotermal, solvotermal, metode oksidasi langsung, deposisi uap kimia, elektrodeposisi dan sol gel [9].

Diantara semua metode, teknik sol gel sangat berguna untuk preparasi material amorf dan kristal. Ini menawarkan keuntungan seperti kemungkinan mendapatkan bahan hibrida homogen pada suhu rendah. Dengan metode sol-gel, TiO₂ berstruktur nano telah banyak disintesis dari hidrolisis prekursor titanium. Keuntungan dari proses sol-gel adalah tidak mahal, serta metode pemrosesan yang mudah untuk pembuatan bubuk titania [10].

Pada penelitian sintesis nanotitania dengan menggunakan metode sol gel, beberapa diantaranya ada yang menambahkan variasi surfaktan untuk melihat bagaimana pengaruh surfaktan terhadap sifat nanotitania tersebut. Hasilnya, pada beberapa penelitian penambahan surfaktan dapat menghasilkan lebih dari satu fasa TiO_2 . Rahayu *et al* [11] dalam penelitiannya membuat nanotitania dengan metode sol gel, bahan prekursor titanium butoksida dan pelarut etanol yang divariasikan dengan penambahan etanolamina, etanolamina sendiri merupakan salah satu jenis surfaktan nonionik. Kemudian dikalsinasi pada suhu 500°C selama 4 jam, didapatkan bahwa penambahan etanolamina sebanyak 1 ml fasa yang terbentuk adalah fasa anatase dan brookite dengan presentase berat 64,07 %wt dan 35,935 %wt, serta ukuran partikel dalam kisaran 19,8 nm.

Maka pada artikel ini akan dilakukan pembuatan TiO_2 dengan metode sol gel. TiO_2 dibuat dengan dengan memvariasikan surfaktan etanolamina 0; 0,5; 1; 1,5; dan 2 ml. Tujuan dari penelitian ini adalah untuk mengetahui pengaruh etanolamina terhadap pembentukan fasa, ukuran partikel, dan luas permukaan nanotitania.

METODE PENELITIAN

Penelitian ini menggunakan bahan titanium butoksida ($\text{C}_{16}\text{H}_{36}\text{O}_4\text{Ti}$) (Sigma Aldrich), etanol ($\text{C}_2\text{H}_5\text{OH}$) (Merck), etanolamina (Merck), dan HCl 37%. Metode penelitian yang dilakukan pada penelitian ini terdiri atas beberapa tahap antara lain sintesis **Tabel 1**. Variasi komposisi sampel.

Sampel	Ti-Butoksida (ml)	Etanol (ml)	HCl 37% (ml)	Ethanolamina (ml)
A-0,0,0	5,25	60	2,45	0
A-0,0,0,5	5,25	60	2,45	0,5
A-1,0	5,25	60	2,45	1,0
A-1,5	5,25	60	2,45	1,5
A-2,0	5,25	60	2,45	2,0

Ti butoksida, kalsinasi, uji karakterisasi sampel menggunakan XRD, TEM, dan SAA.

Proses sintesis dilakukan dengan membuat larutan titania dengan mencampurkan etanol 60 ml dan titanium butoksida 5,25ml dengan mikro pipet, larutan terus diaduk selama ± 20 menit, tahap selanjutnya yaitu dicampurkan etanolamina setetes demi tetes dengan variasi (0, 0,5, 1, 1,5, dan 2 ml) menggunakan mikro pipet sembari tetap diaduk selama ± 30 menit. Selanjutnya HCl dimasukkan setetes demi dengan tetap diaduk selama 24 jam. Variasi komposisi dari kelima sampel tersebut ditunjukkan pada **Tabel 1**. Setelah semua bahan tercampur, sampel akan dikeringkan menggunakan oven dengan suhu 200°C selama 24 jam, lalu suhu dinaikkan secara bertahap.

Kalsinasi dilakukan untuk menghilangkan zat-zat yang tidak dibutuhkan dalam bubuk TiO_2 dan kadar uap air yang berlebihan. Kalsinasi dilakukan selama 4 jam pada suhu 500°C . Setelah proses kalsinasi, sampel yang berbentuk serbuk kemudian digerus

secara manual menggunakan mortar dan pastel agate. Serbuk TiO_2 yang dihasilkan akan dikarakterisasi dengan XRD, TEM, dan SAA.

Proses karakterisasi XRD dimulai dengan sampel berupa serbuk ditempelkan pada lempeng tipis berbentuk persegi panjang (*holder*). Spesimen serbuk dipasang pada pemegang dengan memadatkan terlebih dahulu atau dipasang

langsung ke dalam pemegang spesimen. Lalu memasukkan parameter pengukuran pada *perangkat lunak* pengukuran melalui komputer pengontrol, yaitu meliputi penentuan *scan mode*, penentuan rentang, sudut, kecepatan *scan* cuplikan dan memberi nomor urut file data. Mengoperasikan alat difraktometer dengan perintah “start” pada *menu* komputer, dimana Sinar-X akan meradiasi sampel yang terpancar dari target Cu dengan panjang gelombang 1,5406 Å. Melihat hasil difraksi pada komputer dan intensitas difraksi pada sudut 2θ tertentu, kemudian dicetak oleh mesin printer. Mengambil sampel setelah pengukuran cuplikan selesai. Data yang terekam berupa sudut difraksi (2θ), besarnya intensitas (I) dan waktu pencatatan perlangkah (t).

Proses karakterisasi TEM diawali dengan preparasi sampel, yakni mencampurkan sampel dengan dispersan. Selanjutnya, sampel diletakkan pada *grid* atau substrat dan memasukkannya ke dalam alat. Setelah itu dilakukan pengaturan tegangan, penentuan fokus dan daerah. Kemudian dilakukan penembakan elektron dari senjata elektron yang kemudian akan difokuskan dengan lensa kondensor dan menembus sampel sehingga menghasilkan foto dengan skala pengukuran tertentu. Hasil foto ini kemudian diolah menggunakan perangkat lunak ImageJ untuk menghitung ukuran butiran partikel.

Karakterisasi SAA didasarkan pada siklus adsorpsi dan desorpsi isoteremis gas nitrogen oleh sampel berupa serbuk pada suhu nitrogen cair. Dengan cara sejumlah volume gas nitrogen yang diketahuidimasukkan ke dalam tabung sampel, maka sensor tekanan akan menghasilkan data tekanan proses yang bervariasi. Selanjutnya, data yang dihasilkan dari alat tersebut dihitung dengan metode BET (Braunauer-Emmett-Teller) untuk mencari luas permukaan padatan.

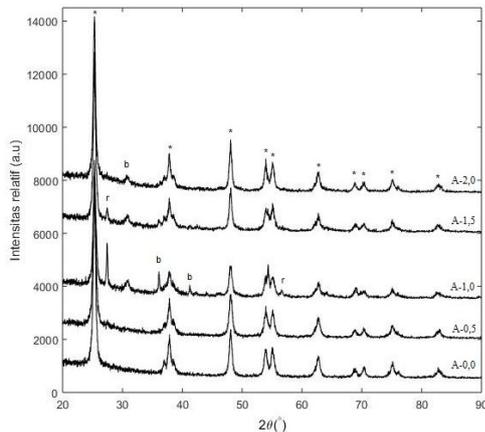
HASIL DAN PEMBAHASAN

Hasil XRD berupa difaktogram hubungan antara intensitas dengan sudut 2θ . Berdasarkan hasil XRD tersebut dapat dilakukan analisis kualitatif yaitu untuk mengetahui struktur dan fasa kristal, dan analisis kuantitatif yaitu untuk mengetahui komposisi pada masing-masing fasa kristal.

Panjang gelombang yang digunakan pada pengujian ini adalah $K-\alpha_1$ sebesar 1,54059 Å. Sudut difraksi (2θ) yang digunakan mulai dari 10° sampai 90° dengan ukuran langkah sebesar $0,02^\circ$ dan *scan time* selama $10^\circ/\text{menit}$. Alat ini dioperasikan dengan tegangan 40 kV dan kuat arus 30 mA. **Gambar 1** menunjukkan difaktogram XRD sampel TiO_2 yang telah dikalsinasi pada suhu 500°C . Tampak bahwa terdapat puncak difraksi $2\theta = 25,32^\circ, 37,80^\circ, 48,01^\circ, 53,87^\circ, 55,02^\circ, 62,8^\circ, \text{ dan } 74,97^\circ$ yang mengindikasikan fasa dari anatase (ICOD 01-078-2486) dengan bidang refleksi yang memiliki indeks miller (101), (004), (200), (105), (211), (204), (107). Selain itu, puncak-puncak yang mengindikasikan adanya fasa brokit (COD 96-900-4140) pada $2\theta = 30,80^\circ, 36,58^\circ, \text{ dan } 41,28^\circ$ dengan bidang hkl (121), (210),

dan (111) serta fasa rutil (ICOD 01-076-1938) pada $2\theta = 27,41^\circ$, dan $56,59^\circ$ dengan bidang hkl (110) dan (220).

Jika melihat hasil difaktogram pada sampel A-0 dan A-0,5 puncak yang dominan muncul adalah anatase, untuk sampel A-0,5 bisa dikarenakan penambahan etanolamina yang masih terlalu sedikit, sehingga tidak menumbuhkan fasa lain. Untuk sampel A-1,0 jika dilihat dari hasil difaktogram terdapat tiga fasa yang muncul



Gambar 1. Difaktogram XRD. * = anatase, b = brookite dan r = rutil.

yaitu anatase, brookite, dan rutil munculnya ketiga fasa tersebut juga ada pada sampel A-1,5 dengan intensitas puncak rutil yang sedikit menurun. Sedangkan untuk sampel A-2,0 hanya muncul fasa anatase dan brookite.

Hal yang sangat menarik dari penelitian ini adalah kemunculan fasa brookite dan rutil yang cukup memadai pada sampel A-1,0. Kemunculan fasa brookite dan rutil dapat dijelaskan dengan melihat hasil difaktogram untuk sampel A-1,0. Biasanya fasa rutil baru muncul pada suhu di atas 500°C dan brookite muncul di bawah 500°C . Namun dalam penelitian ini terutama pada sampel A-1,0 telah muncul fasa brookite dan rutil pada suhu 500°C .

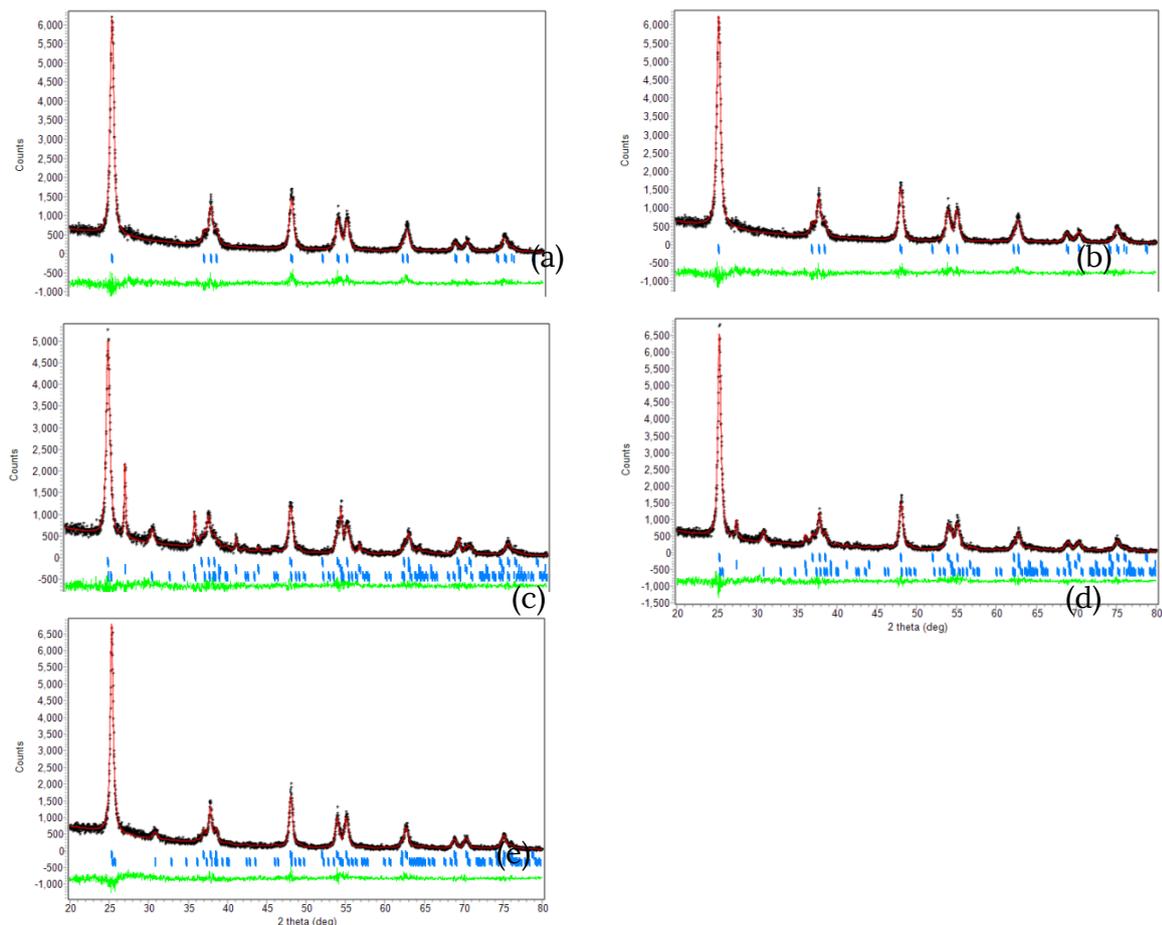
Ini dapat difahami bahwa kehadiran etanolamina pada 1 ml dapat memberi pengaruh kemunculan brookite dan rutil lebih awal. Maksudnya adalah fasa rutil biasa muncul di atas suhu 500°C , akan tetapi pada penelitian ini sudah muncul pada suhu 500°C . Begitu juga sebaliknya pada suhu 500°C fasa brookite biasanya sudah berubah menjadi anatase akan tetapi dalam penelitian ini masih menyisakan fasa brookite.

Menurut Bokhimi *et al* (2002) [12] dan Galkina *et al* (2011) [13] dalam penelitiannya dikatakan bahwa pembentukan fasa rutil bersama dengan fasa anatase ditemukan sebagai hasil peptisasi yang dicapai oleh surfaktan dan HCl. Ketika bubuk dianil, dehidroksilasi menghasilkan cacat kisi yang menghasilkan mikrostrain dan menciptakan kondisi untuk penataan ulang oktahedron paralel dalam kasus anatase (oktahedra terhubung pada simpulnya) ke oktahedron yang diputar 90° dalam kasus rutil (oktahedra terhubung di tepinya). Oleh karena itu, transformasi fasa dari anatase ke rutil dapat dianggap sebagai polimorfisme rekonstruktif dengan perubahan simetri atau sebaliknya.

Kemudian munculnya fasa brookite bisa disebabkan karena menurunnya nilai pH pada sampel [14]. Menurut Hu *et al* (2003) sintesis TiO₂ dengan pH rendah dapat memunculkan fasa brookite, pada penelitiannya fasa brookite muncul pada sampel dengan pH 2 dan suhu kalsinasi 500°C, menurutnya semakin besar pH dan suhu kalsinasi maka fasa brookite tidak muncul. Oleh karena itu, pH optimum yang sesuai untuk sintesis nanopartikel TiO₂ dengan kandungan fasa brookite yang tinggi adalah pH 2 yang sesuai dengan literatur [15].

Analisis kuantitatif dilakukan untuk mengetahui komposisi setiap fasa-fasa tersebut, yang dilakukan dengan refinement data XRD menggunakan metode Rietveld dan perangkat lunak Rietica. Hasil penghalusan ditunjukkan dalam **Gambar 2**. Dalam melakukan penghalusan difaktogram menggunakan metode Rietveld perlu diperhatikan nilai GoF (Godness of Fit). Nilai GoF yang disimbolkan dengan $2 \leq 4$ pun sudah dapat diterima. Selain itu untuk nilai R_{wp} , R_p , dan R_{exp} harus kurang dari 20.

Setelah selesai merefine masing-masing data dapat dilihat harga R pada file output Seperti yang disajikan pada **Tabel 1**. Pada **Tabel 2** ditunjukkan limpahan masing-masing fasa yang ada dalam sampel. Berdasarkan data pada **Tabel 1** penghalusan pada seluruh sampel menunjukkan nilai R_{wp} , R_p , dan R_{exp} kurang dari 20 dan nilai GoF kurang dari 4



Gambar 2. Hasil refinement data XRD TiO₂ (a) A-0,0,0 (b) A-0,0,5 (c) A-1,0 (d) A-1,5 (e) A-2,0

serta kesesuaian pola dengan model yang cukup memadai. Sehingga nilai ini memenuhi standar metode Rietveld.

Hasil penghalusan ditunjukkan dalam **Gambar 2**, terlihat bahwa berdasarkan pola garis selisih antara data pengamatan (berwarna hitam) dan hasil perhitungan (garis hijau) memiliki pola hampir rata yang berarti bahwa selisih antara hasil perhitungan dan data pengamatan relatif kecil.

Dari **Table 2** dapat dilihat bahwa penambahan ethanolamina 0.5 ml tidak memberikan pengaruh kehadiran fasa lain selain anatase. Penambahan ethanolamina 1; 1.5; dan 2 ml dapat menghasilkan fasa brookite dan rutile dengan presentase berat maksimum pada 1 ml. Selain itu dari Tabel 2 juga menunjukkan bahwa berat kandungan fasa anatase semakin naik dengan seiring penambahan ethanolamina, tetapi menurunkan kandungan fasa rutile dan brookite. Hal bisa disebabkan karena fasa rutile berubah menjadi fasa anatase pada penambahan ethanolamina. Gribb and Banfield (1997) [16] mengemukakan bahwa jumlah lokasi inti potensial adalah faktor pembatas dalam laju transformasi anatase-rutile.

Selain itu, tekanan yang kecil pada kristal anatase dapat meningkatkan laju reaksi dengan mengurangi energi regangan yang menyertai pembentukan inti rutil pada suhu rendah, begitupun sebaliknya. Selain itu, data eksperimental dan analisis teoritis menunjukkan bahwa kestabilan anatase dan rutil dapat berbalik ketika ada kontribusi energi permukaan terhadap total energi bebas.

Selain digunakan untuk mengetahui presentase fasa, analisis secara kuantitatif dapat juga digunakan untuk menentukan parameter sel dan grup ruang kristal. Kristal TiO_2 memiliki kemiripan struktur cukup tinggi dengan *database* hasil proses pencocokan dalam hal ini anatase (ICOD 01-078-2486). Berdasarkan *database* tersebut, maka kristal anatase memiliki struktur tetragonal dengan grup ruang 141/AMD dan tidak mengalami perubahan seiring bertambahnya ethanolamina. Selain itu, brookite memiliki struktur ortorombik dengan grup ruang P B C A sedangkan rutile memiliki struktur tetragonal dengan grup ruang P42/M N M sesuai dengan *database* masing-masing.

Setiap kristalin tidak mengalami perubahan struktur. Selain struktur kristal, dapat diketahui juga nilai parameter sel untuk setiap fasa yang diperoleh dari keluaran refinement sampel.

Tabel 2. Parameter kesesuaian refinement data XRD TiO_2

Sampel	R_{wp}	R_p	R_{exp}	GoF
A-0	15,26	11,01	10,20	2,2
A-0,5	15,15	11,01	10,20	2,2
A-1,0	14,63	10,56	10,21	2,0
A-1,5	14,40	10,33	10,22	2,0
A-2,0	14,80	10,67	10,41	2,0

Tabel 3. Presentase fasa TiO₂ dalam persen berat (%wt)

Sampel	Anatase (%wt)	Brookite (%wt)	Rutile (%wt)
A-1,0	57,65 ± 1,6	27,06 ± 1,8	15,29 ± 0,4
A-1,5	69,96 ± 1,6	24,52 ± 1,5	5,52 ± 0,3
A-2,0	78,53 ± 1,6	21,47 ± 1,5	

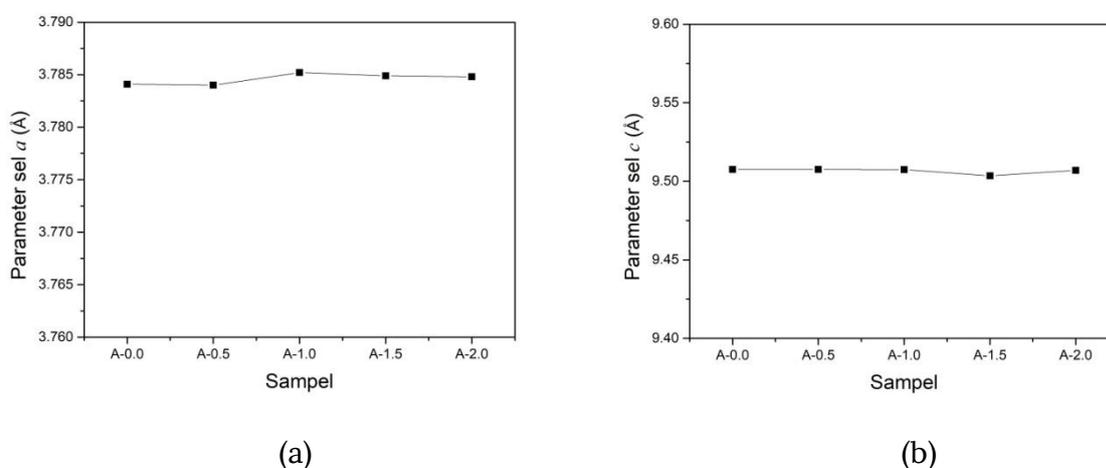
Tabel 4. Parameter sel TiO₂ fasa rutile

Sampel	<i>a</i> (Å)	<i>b</i> (Å)	<i>c</i> (Å)	α (°)	β (°)	γ (°)
A-0,0						
A-0,5						
A-1,0	4,5950	4,5950	2,9582	90	90	90
A-1,5	4,5922	4,5922	2,9572	90	90	90
A-2,0						

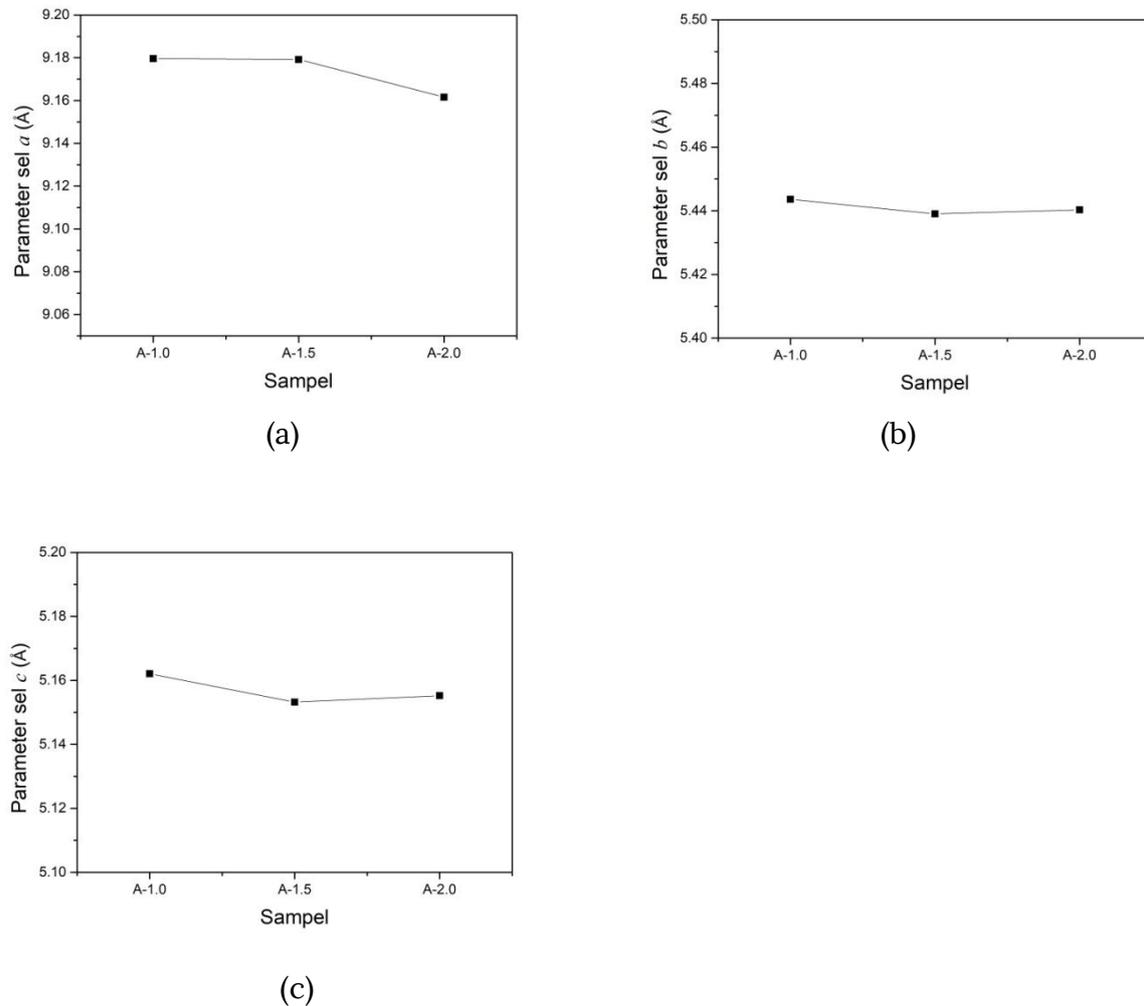
Parameter sel anatase dan brookite tersebut ditunjukkan pada **Gambar 3**, **Gambar 4** dan rutile pada **Tabel 3**.

Gambar 3 merupakan grafik sel parameter untuk fasa anatase, karena parameter $a = b \neq c$, maka grafik parameter sel yang digunakan hanya a dan c . Gambar 4.6. menunjukkan bahwa sel parameter $a = b$ mengalami penurunan pada sampel A-0,5 kemudian kembali naik pada sampel A-1,0 dan mengalami penurunan kembali seiring ditambahkan ethanolamin. Sedangkan untuk sel parameter c terjadi penurunan dan kenaikan kembali, Hal ini berarti bahwa penambahan ethanolamina berpengaruh pada perubahan sel parameter untuk fasa anatase. Perubahan konstanta kisi anatase diperkirakan berasal dari mikrostrain yang diinduksi dari kekosongan oksigen, tekanan hidrostatik, atau kation tertentu.

Kemudian, **Gambar 4** merupakan grafik sel parameter untuk brookite, dimana untuk sel parameter brookite adalah $a \neq b \neq c$. **Gambar 4** menunjukkan bahwa sel parameter a mengalami penurunan seiring dengan bertambahnya ethanolamina.

**Gambar 3.** Sel parameter fasa anatase (a) sel parameter $a = b$, (b) sel parameter c

Gambar 4 menunjukkan bahwa sel parameter a mengalami penurunan seiring dengan bertambahnya ethanolamina. Kemudian sel parameter b dan c mengalami kenaikan seiring dengan pertambahan ethanolamina. Hal ini berarti bahwa penambahan ethanolamina berpengaruh pada perubahan sel parameter untuk fasa brookite.



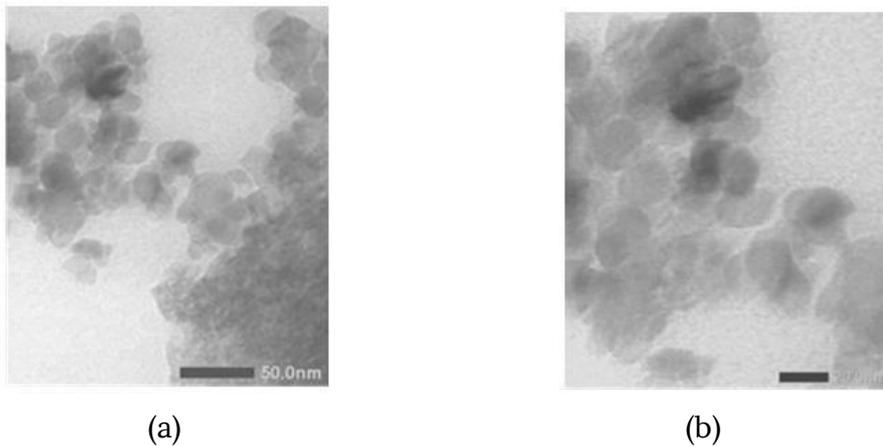
Gambar 4. Sel parameter fasa brookite (a) sel parameter a (b) sel parameter b , dan (c) sel parameter c

Hasil TEM dilakukan pada sampel A-1,0 dengan skala bar 50 nm dan 20 nm. Adapun hasil analisis morfologi dan distribusi ukuran partikel ditunjukkan pada **Gambar 5**. Dalam pengukuran ini, untuk skala bar 50 nm diambil 20 partikel dengan ukuran yang berbeda, dan skala bar 20 nm diambil 15 partikel dengan ukuran berbeda untuk memperoleh rata-rata ukuran partikel.

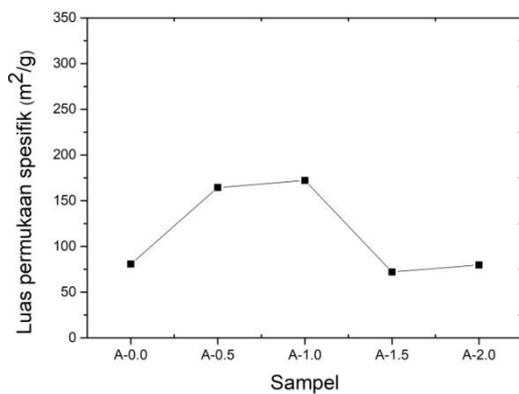
Dari kedua gambar TEM ini baik skala bar 50 dan 20 nm memberikan hasil masing-masing $14,8 \pm 0,2$ nm dan $16,8 \pm 0,4$ nm. Dengan demikian dari segi ukuran partikel berdasarkan hasil TEM ini, klasifikasi sampel dapat masuk ke kelompok nanopartikel [17]. Dari kedua gambar TEM ini sampel dapat dikatakan tidak mengalami

perlengketan antara partikel-partikel sehingga partikel-partikel tidak mengalami *adhesion* [18], dan bentuk partikel secara umum masuk bentuk bola (*spheris*).

Hasil SAA digunakan untuk mengetahui luas permukaan spesifik dari sampel, maka dilakukan uji menggunakan SAA dengan metode BET. Luas permukaan spesifik metode BET dihitung melalui proses adsorpsi-desorpsi nitrogen pada kondisi setimbang dalam suhu nitrogen cair (77 K) menggunakan SAA *Quantachrome NOVA 1000e* versi 11.0.



Gambar 5. Hasil TEM sampel A-1,0 (a) dengan skala bar 50 nm dan (b) dengan skala bar 20nm.



Gambar 6. Grafik luas permukaan spesifik.

Gambar 6 merupakan hasil dari luas permukaan spesifik sampel TiO₂. Untuk luas permukaan spesifik terkecil ada pada sampel A-1,5 sebesar 72,072 m²/g sedangkan untuk luas permukaan spesifik terbesar diperoleh pada sampel A-1,0 dengan nilai 172,239 m²/g. Sampel A-0,0 memiliki luas permukaan spesifik 80,680 (m²/g). Sampel A-0,5 luas permukaan spesifik 164,376 (m²/g). Kemudian sampel A-2,0 didapatkan dan luas permukaan spesifik 79,72 (m²/g). Analisis luas permukaan dapat menunjukkan peningkatan dan penurunan luas permukaan TiO₂ dengan penambahan ethanamina yang berbeda-beda.

KESIMPULAN

Hasil karakterisasi menunjukkan bahwa penambahan ethanamina mempengaruhi fasa kristal yang terbentuk, ukuran partikel dan luas permukaan yang dihasilkan. Dari hasil analisis XRD didapatkan untuk sampel A-0 dan A-0,5 fasa kristalnya adalah murni anatase, sedangkan sampel A-1,0 dan A-1,5 fasa yang didapatkan adalah anatase, brookite, dan rutile. Nilai presentase berat masing masing fasa pada sampel A-1,0 sebesar $57,65 \pm 1,6$ %wt; $27,06 \pm 1,8$ %wt, dan $15,29 \pm 0,4$ %wt. Sedangkan untuk sampel A-1,5 sebesar $69,96 \pm 1,6$ %wt; $24,52 \pm 1,5$ %wt, dan $5,52 \pm 0,3$ %wt. Sampel A-2,0 hanya menghasilkan fasa anatase dan brookite saja dengan presentase berat masing-masing $78,53 \pm 1,5$ %wt dan $21,47 \pm 1,5$ %wt.

Dari hasil analisis TEM yang dilakukan pada sampel A-1,0 didapatkan ukuran partikel sebesar $15,8 \pm 1,0$ nm. Hasil analisis SAA sampel A-1,0 menghasilkan luas permukaan spesifik terbesar yaitu $172 \text{ m}^2/\text{g}$, luas permukaan spesifik terkecil dihasilkan pada sampel A-1,5 yaitu $72,07 \text{ m}^2/\text{g}$.

UCAPAN TERIMAKASIH

Penulis mengucapkan terimakasih kepada Dikti yang telah mendanai penelitian ini melalui skema penelitian hibah Pascasarjana dengan nomor kontrak: 3869/UN26.21/PN/2020.

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MODELING AUTOREGRESSIVE INTEGRATED MOVING AVERAGE (ARIMA) AND FORECASTING OF PT UNILEVER INDONESIA TBK SHARE PRICES DURING THE COVID-19 PANDEMIC PERIOD

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Abstract

ARIMA method is one method that can be used in predicting the movement of company shares. This study aims to obtain a time series model with the ARIMA method and predict stock price data of PT Unilever Indonesia Tbk from January 2020 to June 2020. The best model that fits the data based on the MSE value is the ARIMA(1,1,1) model. The ARIMA model (1,1,1) shows a match between real data and the predicted value. This model is then used for forecasting the next 14 days. Data on UNVR stock price from January 2020 to June 2020 are below 8000, this seems to correlate with the current conditions, namely the Covid-19 pandemic. Forecasting for the next 14 days (two weeks) from July 1, 2020 to July 14, 2020, the forecast values have a trend decrease, the trend of PT. Unilever Indonesia Tbk has been going down since January 2020. This seems to have occurred as an implication of the Covid-19 pandemic from January 2020 to the present.

Keywords: time series, ARIMA, COVID-19, forecasting

Introduction

Time series analysis has become a topic and study that has attracted the attention of many researchers in statistics, economics, finance, population and other fields of science. The application of time series analysis is mainly used for

forecasting in various fields. Time series data is data that is recorded during a certain period. Usually in the form of daily, weekly, monthly, six-monthly and annual data. The pattern can be in the form of repetition of the past or does not have a pattern. Time series data that has a repetition pattern is called seasonal time series, for example is data on a company's stock movements. In the case of non-seasonal time series, the Box Jenkins method is modelled by determining several criteria which are then known as the ARMA and ARIMA models. These criteria include the Autocorrelation (ACF) and Partial Autocorrelation (PACF) functions. Similar to the case of seasonal time series, Box Jenkins models using the same criteria. Forecasting is a conjecture or



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estimate about the occurrence of a situation in the future by using certain methods. Forecasting is done by using the best information so that the desired goals can be achieved.

Forecasting methods commonly used are Autoregressive Integrated Moving Average (ARIMA). The Integrated Moving Average Autoregressive Model (ARIMA) is a model that uses dependent variables or data in the past and completely ignores the independent variables. This method has several advantages, namely not requiring stationary data patterns and can be used on data that form seasonal patterns [1]. Therefore ARIMA is a statistic that is suitable to be used in predicting a number of variables quickly, simply and accurately because it only requires variable data to be predicted. Therefore in this study the ARIMA model for time series data analysis and forecasting using PT Unilever Indonesia Tbk (UNVR) stock price data from January 2, 2020 to June 30, 2020.

Statistical Model 2.1

Data Time series

The time series is a collection of observations X_t , each observation that is collected at time t . The time series model in observational data X_t is a specification of the joint distribution (or maybe only the mean and covariance) of the random variable array X_t . The most important part of time series analysis is the selection of possible models that fit the data. Time series data itself is data collected from time to time for an individual [2].

2.2 Stationarity

Stationary means there is no drastic change in the data. Data fluctuations are around a constant average value, independent of the time and variance of these fluctuations. The assumption of stationarity in time series data analysis is fundamental and must be checked before analyzing data. Several methods are available to check stationarity of time series data, based on data plots or through the test Augmented Dickey-Fuller (ADF). The ADF test process is as follows, for example y_1, y_2, \dots, y_n becomes a time series, assuming that $\{y_t\}$ follows the AR(p) model with the given μ :

$$y_t - \mu = \phi_1(y_{t-1} - \mu) + \dots + \phi_p(y_{t-p} - \mu) + \varepsilon_t \quad (1)$$

where:

ε_t is the white noise average 0 and variance σ^2 , and $\varepsilon_t \sim N(0, \sigma^2)$.

Testing non-stationary data in equation (1) using the ADF test or tau test (τ) is carried out as follows:

$H_0 : \phi_1^* = 0$ (there are root units or non-stationary time series)

$H_1 : \phi_1^* < 0$ (no root units or stationary time series)

Test statistics:

ADF test

$$(\tau) = \frac{\hat{\phi}_1^*}{\text{se}_{\hat{\phi}_1^*}} \quad (2)$$

for significance level ($\alpha = 0.05$), reject H_0 if $\tau < -2.57$ or if p-value < 0.05 [2],[8].

2.3 Model Autoregressive (AR)

Model autoregressive (AR) is a model that illustrates that present value is influenced by past value. The AR model with order p is denoted by AR (p). The general form of the AR (p) model is:

$$Y_t = C + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \dots + \phi_p Y_{t-p} + \varepsilon_t \quad (3)$$

Where:

C : Constant,

ϕ_p : Coefficient parameter AR with order p,

Y_t : Data at time t,

ε_t : Error at time t.

Order in the model AR is often used in time series analysis is p=1 or p=2 [3].

2.4 Model Moving Average (MA)

Model Moving Average has the form as follows:

$$Y_t = C + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \dots - \theta_q \varepsilon_{t-q} \quad (4)$$

Where:

C : Constant,
 θ_q : Coefficient parameter MA of order q ,
 Y_t : Data at time t ,
 ε_t : error at time t .

From equation (4), it can be seen that Y_t is the weighted average error of q periods backwards. The number of errors q used in this equation indicates the level of the moving average model.

2.5 Model ARIMA

The Integrated Moving Average Autoregressive Model (ARIMA) was developed by George E.P. Box and Gwilym M. Jenkins (1976), so ARIMA is also called the Box-Jenkins time series method. The ARIMA model is divided into 3 elements, namely the Autoregressive (AR) and Moving Average (MA) and Integrated (I) models.

The ARIMA model is a model that completely ignores independent variables in making forecasting. ARIMA uses past and present values of the dependent variable to produce accurate short-term forecasting. ARIMA is very good accuracy for short-term forecasting, while for long-term forecasting is not good. Usually it will tend to be flat (horizontal/constant) for a fairly long period. The general form of the ARIMA model can be stated in the following equation [4]:

$$\phi_p(B)\nabla^d Y_t = C + \theta_q(B)\varepsilon_t \quad (5)$$

Where:

Y_t : Data at time t ,
 ϕ_p : Parameter Autoregressive (AR)
 B : Backward Operator,
 d : Order of differencing,
 C : Parameter constant,
 θ_q : Parameter Moving Average (MA),
 ε_t : error at time t .

The ARIMA model assumes that the input data must be stationary. Stationary means that there is no growth or decrease in the data. The data must be roughly horizontal along the time axis. In other words, data fluctuations are around an average value and a variance that is constant with time. If the input data is not stationary, adjustments are needed to produce stationary data. One of the commonly used methods is the differencing method. This method is done by reducing the value of data in a period with the data value of the previous

period. One method that can be used to estimate model parameters is Least Squares (Conditional Least Squares) [5]. The least squares method is done by minimizing the number of error squares. The steps for applying the ARIMA method in a row are model identification, model parameter estimation, model evaluation.

2.6 Test for Stability of the model

The Eigen value of matrix F satisfies

$$|I_n\lambda - \phi_1\lambda^{p-1} - \phi_2\lambda^{p-2} - \dots - \phi_p| = 0 \quad (6)$$

is covariance stationary as long as $|\lambda| < 1$ for all values of λ . Or equivalently, the VAR is covariance stationary if all values of z are satisfying

$$|I_n - \phi_1z - \phi_2z^2 - \dots - \phi_pz^p| = 0 \quad (7)$$

It lies outside the unit circle ([9],[10],[11]).

2.7 The steps of ARIMA method

The steps in applying the ARIMA method in succession are:

2.7.1 Data stationarity test

The first thing to do at this stage is whether the time series data is stationary or non-stationary and that the AR and MA aspects of the ARIMA model only relate to stationary time series [6]. The stationarity of a time series can be seen from the ACF plot, where the autocorrelation coefficient decreases rapidly to zero, usually after the 2nd or 3rd lag. If the data is not stationary then a distinction can be made, the order of differentiation until the series becomes stationary can be used to determine the value of d on ARIMA (p, d, q).

2.7.2 Parameter estimation model

Parameter estimation by trying various ARIMA models at each level of each order which is likely to be an ARIMA parameter.

2.7.3 Model Evaluation

The second step is to estimate the autoregressive parameters and moving average parameters based on the order obtained at the identification stage. A good estimation model can be seen from the significance of the estimated parameters, and the smallest mean square error (MSE) value [7].

2.7.4 Forecasting

The last stage is forecasting, which is to make predictions or estimates of data based on the selected ARIMA model.

Results and Discussion

In doing time series modeling, the first step that must be taken is the data stationarity test. Stationary testing can be done in three ways, namely viewing the time series plot, using the Autocorrelation Function (ACF) graph, and the unit root test (unit root test).

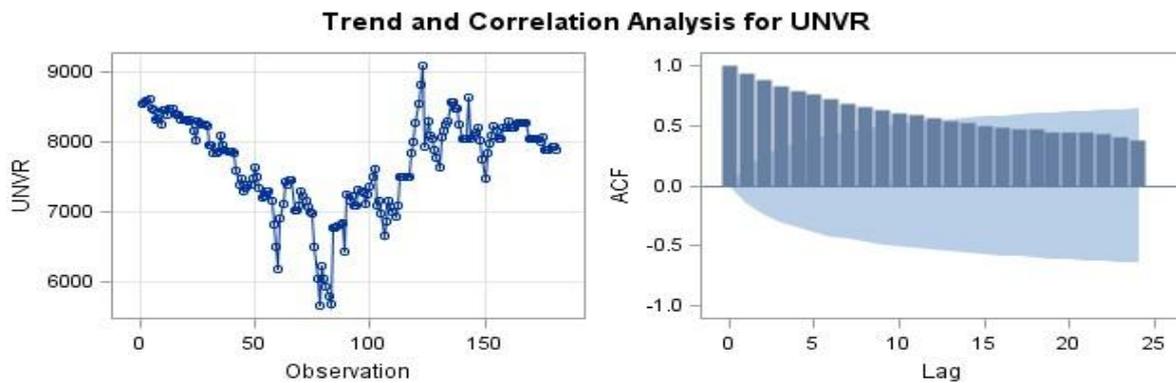


Figure 1. Plot *time series* and ACF Data UNVR

Based on Figure 1, it can be seen that the four data are not stationary in the average or variety because they have a tendency pattern. Furthermore, looking at the ACF graphs from the four images also shows the instability because it has a pattern of decreasing exponentially close to zero. Then finally the stationary testing with the unit root test.

Table 1. Augmented Dickey-Fuller Unit Root Tests

Augmented Dickey-Fuller Unit Root Tests							
Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau	F	Pr > F
Zero Mean	3	-0.1497	0.6479	-0.46	0.5122		
Single Mean	3	-9.0190	0.1653	-2.19	0.2120	2.43	0.4514
Trend	3	-9.3204	0.4742	-2.27	0.4494	2.90	0.5987

Hypothesis test:

H_0 : has a root unit (not stationary)

H_1 : has no unit root (stationary)

Conclusion: Based on Table 1, it can be seen in the statistical p-value that Tau (τ) all types of testing for each variable are greater than the significant level used, which is $\alpha = 0.05$, so that starting with H_0 is not stationary.

Because the data is not stationary, differencing must be performed on the data, then re-testing of stationary testing using time series plots, ACF charts and unit root tests.

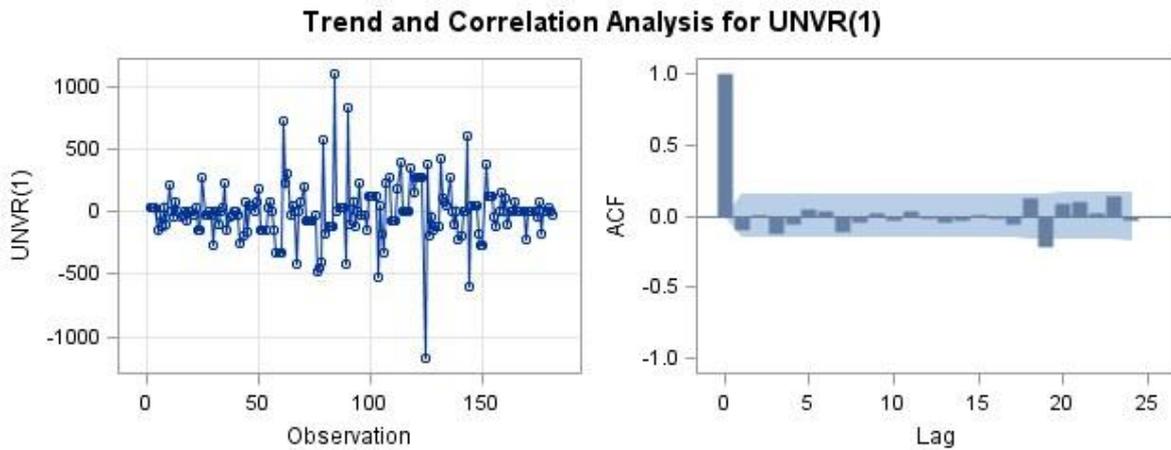


Figure 2. Plot time series and ACF Data share price UNVR after differencing (d=1)

Based on Figure 2, it can be seen that the data shows that they are stationary in mean and variance because they do not have a tendency pattern, then the stationary testing is done by unit root test.

Table 2. Augmented Dickey-Fuller Unit Root Tests after differencing 1
Augmented Dickey-Fuller Unit Root Tests

Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau	F	Pr > F
Zero Mean	3	-493.318	0.0001	-7.97	<.0001		
Single Mean	3	-496.399	0.0001	-7.95	<.0001	31.60	0.0010
Trend	3	-524.471	0.0001	-7.98	<.0001	31.84	0.0010

Hypothesis test:

H_0 : has a root unit (not stationary) H_1 : has no unit root (stationary)

Conclusion: Based on Table 2, it can be seen in the statistical p-value Tau (τ) that all types of tests for each variable are smaller than the significant level used, which is $\alpha = 0.05$, so reject H_0 which means the data has been stationary. After stationary data with the first differencing (d = 1), it can then determine the ARIMA model by looking at the partial autocorrelation (PACF) value and the autocorrelation (ACF) value using the first differencing data.

Table 3. Values of PACF and ACF

Lag	PACF	T	ACF	T	Lag	PACF	T	ACF	T
1	-0,097	-1,3	-0,097	-1,3	16	-0,03097	-0,42	-0,01828	-0,23
2	-0,00265	-0,04	0,006785	0,09	17	-0,09798	-1,31	-0,05759	-0,73

3	-0,12933	-1,74	-0,12851	-1,71	18	0,113378	1,52	0,127839	1,63
4	-0,07878	-1,06	-0,05175	-0,68	19	-0,21548	-2,89	-0,22114	-2,77
5	0,030104	0,4	0,04354	0,57	20	0,011074	0,15	0,08996	1,08
6	0,025691	0,34	0,035005	0,46	21	0,131691	1,77	0,09685	1,16
7	-0,12518	-1,68	-0,11086	-1,44	22	-0,01332	-0,18	0,016706	0,2
8	-0,07151	-0,96	-0,0501	-0,64	23	0,122557	1,64	0,138303	1,64
9	0,028733	0,39	0,0276	0,35	24	0,02544	0,34	-0,03014	-0,35
10	-0,06341	-0,85	-0,03682	-0,47	25	0,064905	0,87	0,012023	0,14
11	-0,00615	-0,08	0,040073	0,51	26	-0,04815	-0,65	-0,03297	-0,38
12	-0,00575	-0,08	-0,01645	-0,21	27	-0,09531	-1,28	-0,07085	-0,83
13	-0,04668	-0,63	-0,04235	-0,54	28	0,065394	0,88	0,009657	0,11
14	-0,05841	-0,78	-0,02922	-0,37	29	0,118954	1,6	0,132628	1,54
15	-0,01335	-0,18	0,008527	0,11	30	0,064168	0,86	0,019758	0,23

Based on Table 3, to find out the order on AR (p) and MA (q) can be seen from the T value in each table with a limit of ± 1.96 . The T value on PACF indicates the order p. Because there are 3 values in the initial lags that exceed the ± 1.96 limit, the order p is 1. While the T value in ACF indicates the order q, where there is 1 value in the initial lags that exceeds the limit of ± 1.96 , meaning that the order q is 1.

After getting each order on AR and MA, then you can try various ARIMA models on each order that are likely to be the parameters of the ARIMA model. Next do a significance test to choose which model is suitable to use. The model is said to be significant, if the p-value parameter is smaller than $\alpha = 0.05$. The possibilities that can be used to become the parameters of the ARIMA model and the results of the significance tests on each of the possible ARIMA models are as follows.

Table 4. The result of the possible significance and MSE value of ARIMA model

Model	Significant	MSE
ARIMA(1,1,0)	No	53340
ARIMA(0,1,1)	No	53329
ARIMA(1,1,1)	Yes	52694

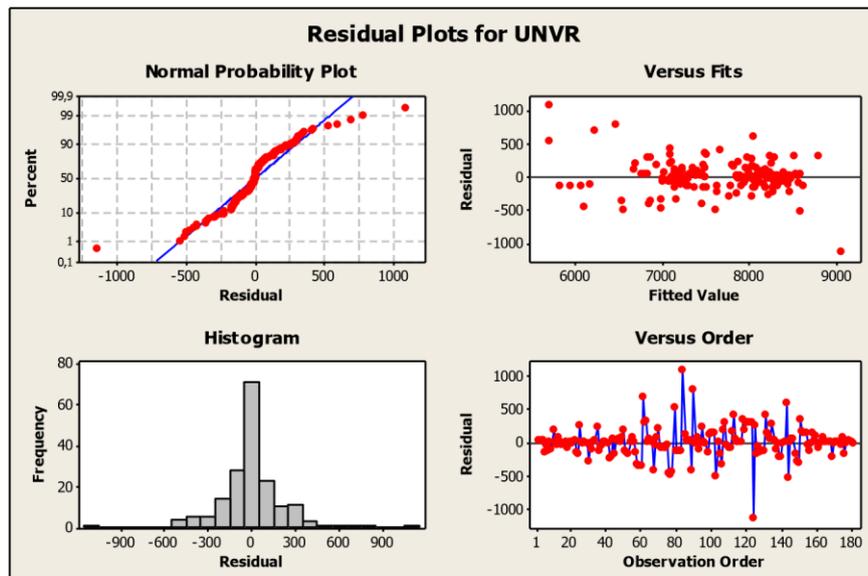


Figure 3. Plot Residual Data Share price UNVR

Based on Table 4, the significant ARIMA model (p -value < 0.05) is ARIMA (1,1,1). And after obtaining some significant ARIMA models, the thing to do next is to evaluate the model to get the best model. The best model is by looking at the smallest MSE value. Based on Table 4 it can be seen that the one with the smallest MSE value among all possible models is ARIMA (1,1,1) with MSE value = 52694. Figure 3 shows the residual plot for UNVR share price data from January 2, 2020 to June 30, 2020. There is an outline of a straight line that can be observed from the normality plot. This indicates that the error is close to normal with some outliers. Therefore, the normal assumptions are met, besides that it can be seen from the histogram plot that the graph looks symmetrical and converges in the middle and shows a slight spread, thus supporting the normality assumption. Therefore ARIMA (1,1,1) was chosen as the best model that can be used if you want to forecast. The results of parameter determination obtained by ARIMA (1,1,1) with coefficients $C = -0,736$, $AR(1) = 0.7684$, and $MA(1) = 0.8747$. Therefore the ARIMA model (1,1,1) can be stated as follows.

$$Y_t = -0.736 + 0.7684Y_{t-1} - 0.8747\varepsilon_{t-1} \quad (8)$$

And the following is the result of forecasting from the stock price data of PT Unilever Indonesia Tbk from July 1 to July 14, 2020:

Table 5. Forecasting data PT Unilever Indonesia Tbk from July 1 to July 14, 2020:

Period	Forecast	Lower	Upper	Real
182	7906,18	7456,17	8356,19	7800
183	7910,19	7306,66	8513,72	8050
184	7912,54	7207,00	8618,07	7900
185	7913,60	7131,64	8695,56	7900
186	7913,69	7070,49	8756,88	7925
187	7913,02	7018,45	8807,59	7900
188	7911,77	6972,60	8850,93	7925
189	7910,07	6931,15	8888,99	8100
190	7908,03	6892,94	8923,12	7975
191	7905,73	6857,19	8954,27	7925
192	7903,22	6823,34	8983,11	8025
193	7900,56	6791,01	9010,11	8075
194	7897,78	6759,93	9035,64	8025
195	7894,91	6729,88	9059,94	8075

From the analysis above model (8), ARIMA (1,1,1) can be relied upon to be used in further studies, especially for forecasting purposes. Based on the results of forecasting, it can be seen that the real and forecast data are almost close to each other.

Conclusion

The UNVR stock price data from January 2020 to June 2020 is modeled with the time series analysis approach and the best model that fits the data based on the MSE value is the ARIMA(1,1,1) model. The ARIMA model (1,1,1) shows a match between real data and the predicted value. This model is then used for forecasting the next 14 days. Data on UNVR stock price from January 2020 to June 2020 are below 8000, this seems to correlate with the current conditions, namely the Covid-19 pandemic. Forecasting for the next 14 days (two weeks) from July 1, 2020 to July 14, 2020, the forecast values have a trend decrease, the trend of PT. Unilever Indonesia Tbk has been going down since January 2020. This seems to have occurred as an implication of the Covid-19 pandemic from January 2020 to the present.

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CYTOTOXIC ACTIVITY OF METHANOL EXTRACTION OF AVICENNIA MARINA AND TAURIN IN THE HELA CANCER CELLS

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Abstract

The aim of study was to determine any anticancer potential from *Avicennia marina* leaf extract compare to taurine on cytotoxic and anti-proliferation activities against *HeLa* cervical cancer cell line by using the MTT method (3- (4, 5-dimethylthiazol-2-yl) - 2, 5- diphenyltetrazolium bromide). The results indicated that methanol extraction of *A. marina* leaf as well as taurine did have cytotoxic and anti-proliferation effects on *HeLa* cell line with IC50 values of 321 ppm and 603 ppm 1000 ppm. While the doubling time value for anti-proliferation of *A. marina* leaf methanol extraction and taurine showed higher values than the control group (72.19 hours).

Keywords : *Avicennia marina*, taurine, cytotoxic, cytotoxic and anti-proliferative, *HeLa* cells

1. INTRODUCTION

The incidence of diseases of Indonesia is ranked 8th in Southeast Asia, and 23rd in the Asian Continent [1]. One of the diseases is cervical cancer which mostly caused by Human Papillomavirus (HPV 18) [2]. Currently cervical cancer is the second leading cause of mortality in women in the world with a new incidence of 570,000 new cases in 2018 representing 6.6% of all cancers affecting women [3]. Various attempts have been made to prevent and cure cancer. However, current cancer treatments are still not effective in healing, some are caused by using chemical drugs which only temporarily and cannot resist selective target cells, on the other hand, causes some damage on normal body cells. Efforts to find alternative natural cancer drugs is needed with high effect on target cells but not

for normal cells by exploring natural sources, one of which is exploring potential drugs derived from mangrove plants, namely *Avicenia marina*.

Avicenia marina is a type of mangrove plants in which with other mangrove plants have been widely used as traditional medicine in many different part of the world. *A. marina* belongs to Acanthaceae family with a height of 14 m and a specialized root structure known as pneumatophores. This *A. marina* is known to contain various bioactive compounds including alkaloids, saponins, triterpenoids, glycosides, tannins, flavonoids which act as drugs and high antioxidants [4]. Other studies also indicated that *A.marina* leaves have the potential to be



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developed as phytopharmaca as well as other *Avicennia* plants [5, 6]. Therefore, in this study we aimed to investigate its function on *HeLa* cervical cancer cell lines compared to those of taurine.

On the other hand, Taurine, which part of free amino acids, known with numerous benefits to human health [7]. Taurine is also indicated to have the ability of antioxidants to prevent oxidative damage to the effects of paraquat induction [8]. Taurine also can be widely found in marine animals such as fish, squid, clams, snails and oysters.

2 METHODS

2.1 Sample Preparation

A. marina leaves was obtained from the Lampung Mangrove Center (LMC) in Labuhan Maringgai of Lampung Province, Indonesia. *A. marina* leaves extraction was carried out at the Biomolecular Laboratory of Biology, Faculty of Mathematics and Natural Sciences, University of Lampung. *A. marina* leaves dried in an oven at 30 °C, then ground to obtain simplicia powder. Maceration was applied to the simplicia powder by using a methanol solvent 1:10 for 24 hours followed by filtration using a bucher funnel and filter paper. The filtrate then was evaporated using a rotary evaporator at 50 °C until an extract was obtained in the form of a paste [9]. Cytotoxic and antiproliferative testing of *HeLa* cells was carried out at the Cell Culture and Cytogenetic Laboratory, Faculty of Medicine, Padjadjaran University [10].

2.2 HeLa Cell Culture Media Preparation

The media was made by dissolving 5 ml of 10% FBS solution, and 0.5 ml Pensterp (Penicillin-Streptomycin) which has been thawed in a sterile water bottle and then added with 50 ml of RPMI 1640 (Rosewell Park Memorial Institute)[10].

2.3 Harvesting and Calculation of HeLa Cell Count

Cells were transferred into a conical tube and 3 ml of media were added and centrifuged at 1500 rpm for 5 minutes. A total of 10 μ l of mixed cells and trypan blue was used to calculate the number of cells by using hemocytometer. Living cells were marked with a clear color while those that were not blue. Calculation with a hemocytometer was done by selecting 4 counting rooms. Following was a series of calculations for the number of cells to be cultured [10]

Align Cell = the cell count for all rooms is calculated 4

Number of cells count / ml = Mean cell x dilution factor x 10^4

Total number of cell needed = total of well x total of sel well

Transfer volume sel = total number of sel needed number of cell count/ml

2.4 Preparation for testing of the extract solution

A stock solution was made by dissolving each extract as much as 10 mg with 1 ml of 1% dimethyl sulfoxide (DMSO), while for taurine as much as 10 mg dissolved with 1 ml of distilled water. The stock solution was then diluted again to a series of concentrations of 125 ppm, 100 ppm, 75 ppm, 50 ppm and 25 ppm. *A. marina* leaf extract solution and taurine in various levels then were tested on HeLa culture cells.

2.5 Cytotoxic test by using MTT (3-(4,5- dimethyliazol-2-il)-2,5-difenil tetrazoliumbromida)

Cells that have been cultured in a well plate for 24 hours were removed from the incubator then the culture media were removed and the cells were rinsed with phosphate buffer saline (PBS). Each well was then given each extract and taurine with a predetermined concentration and incubated again for 24 hours. The test solution was then discarded, and the wells were rinsed with a phosphate buffer saline (PBS) solution. To the well was added 10 μ l MTT (3- (4,5-dimethyliazol-2-il) -2,5-diphenyl tetrazolium bromide) with a concentration of 5 mg / ml phosphate buffer saline (PBS). Then incubated again for 2 hours at 37 °C in a CO₂ incubator. Living cells would metabolize MTT (3- (4,5- Dimethyliazol-2-il) -2,5-Diphenyl Tetrazolium bromide) to formazan giving purple color. The MTT reaction (3- (4,5-dimethyliazol-2-il) -2,5-diphenyl tetrazolium bromide) was stopped with 100% dimethyl sulfoxide (DMSO) stopper reagent as much as 100 μ l per well. The uptake was then read with an ELISA reader at a wavelength of 550 nm [12]

2.6 Antiproliferative test by using MTT (3-(4,5- dimetiltiazol-2-il)-2,5-difenil tetrazoliumbromida)

Cells that had been cultured in hourly well plates were given 100 μ l extracts and taurine with 125 concentration series, respectively; 100; 75; 50; and 25 ppm. Sampling was carried out for incubating with different times, namely, 24 hours, 48 hours, and 72 hours at 37 °C in a CO₂ incubator. The absorbance of each treatment was measured with a wavelength ELISA reader 550 nm. Then a statistical analysis was performed to determine the difference in the number of living cells at different incubation times [11]

2.7 Data Analysis

Cytotoxic tests on *HeLa* cancer cells were carried out using probit analysis to determine the IC₅₀ value of each extract. The percentage of cell viability was obtained by the following formula [12]. Analysis of antiproliferative test for the doubling time value was obtained from the linear regression equation between incubation time vs. log number of living cells. To determine the effect of concentration on the average number of living cells, a statistical analysis of the One Way ANOVA test with SPSS was performed at a 95% confidence level followed by the Least Significant Difference (LSD) test at 5%.

3. RESULTS

3.1 Cytotoxic Test

Based on cytotoxic tests that have been carried out with *A. marina* and taurine leaf extracts against *HeLa* cervical cancer cells, it was obtained that the relationship of extract concentration with cell viability (%) which could be seen in Figure 1, Figure 2 and Figure 3. To understand the cytotoxic effect of the extract and taurine, Doxorubicin as commonly used for cancer drug was applied with 15 and 10 ppm (data for doxorubicin and taurine was shared with Widiastuti *et al*, 2020 unpublished).

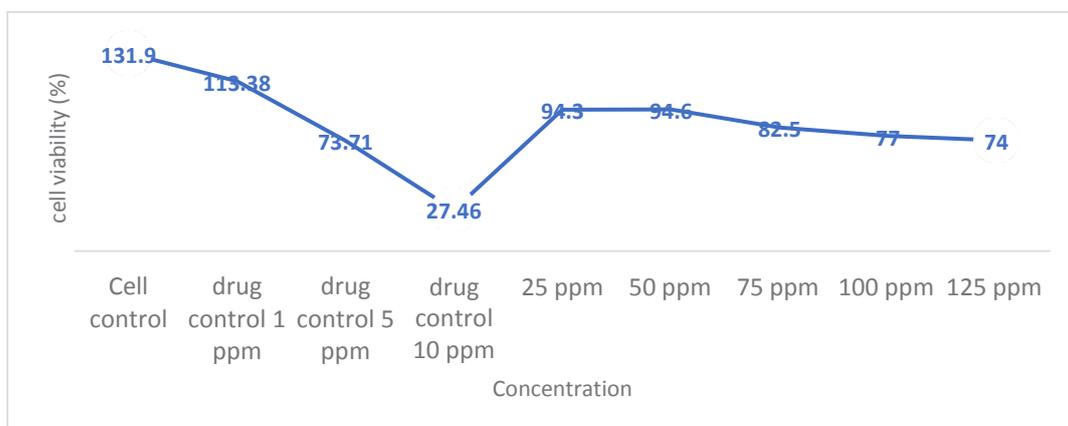


Figure 1. Effect of *A. marina* leaf extract on *HeLa* cell viability (%)

The result indicated that *A. marina* leaf extract with a concentration of 125 ppm showed the lowest viability percentage of 74 % among other concentrations and cell control. This concentration was almost close to those given with Doxorubicin (commonly used for cancer treatment) as much as 5 ppm.

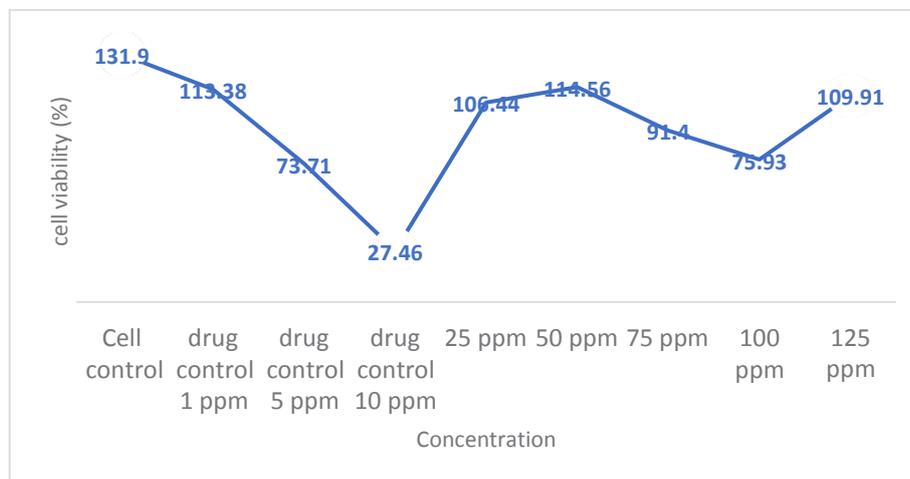


Figure 2. Effect of taurine on HeLa cell viability (%)

Similar to those, given Taurine treatment also showed the lowest cell viability percentage at a concentration of 100 ppm which was indicated for 75.93%, from which the percentage of cell inhibition was 24.07%. Similar to those in *A. marina* extract, this concentration of taurine reduced the viability of the cells indicated by those given doxorubicin at 5 ppm.

The effect of the *A. marina* extract as well taurine at different concentration on cytotoxic activity by looking at the IC₅₀ values could be seen in Table 1 as followed. The IC₅₀ against of *A. marina* lied in 321 ppm and taurine was in 603 ppm while cancer drug, doxorubicin, was in 12.35 ppm.

Tabel 1. Cytotoxic activity of *A. marina* and Taurine on HeLa cell line (IC₅₀ value)

	Concentration Compound (ppm)	Cell Viability (%)	IC ₅₀ (ppm)
<i>A. marina</i>	25	94.3	
	50	94.6	
	75	82.5	321
	100	77	
	125	74	
Taurin	25	106.44	
	50	114.56	
	75	91.4	603
	100	75.93	
	125	109.91	
Doxorubicin	1	113.38	
	5	73.71	12.35
	10	27.46	

The *HeLa* cells morphology from different treatment groups could be seen in Figure 3. Some apoptotic cells indicated with shrinking and irregular shape, while the *HeLa* cell shape was polygonal and attaching to the matrix. Criteria for a cytotoxic activity for crude extracts according to the American National Cancer Institute (NCI) are $IC_{50} < 30 \mu\text{g/ml}$ [13].

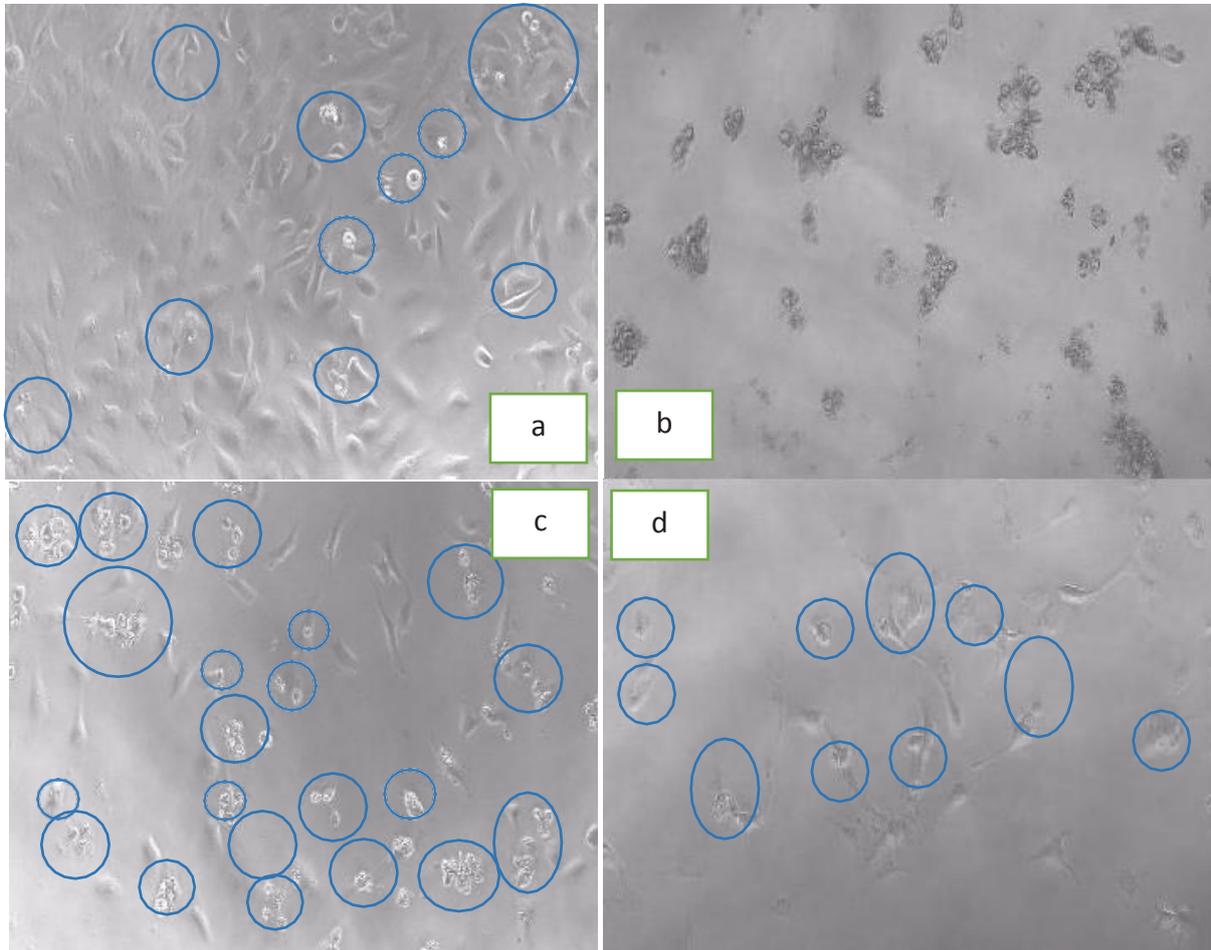


Figure 3. The appearance of *HeLa* cell morphology in cell control (a), drug control with doxorubicin (b), 75 ppm concentration *A. marina* methanol extract treatment (c), 100 ppm concentration taurine treatment (d). Note: ○ : apoptotic cells

The doubling time of the *HeLa* Cell line with different treatment groups could be seen in Table 2. Doubling time was determined to understand how much time was needed for the culture cells to increase their number or to proliferate.

Tabel 2. Doubling Time of *A. marina* and Taurine on HeLa cell line

Treatment groups	Concentration (ppm)	Incubation time line equation and log of cell count	Slope	Doubling Time (h) value
<i>A. marina</i>	25	$0.0721x + 4.1948$	0.0721	562
	50	$0.0348x + 4.2329$	0.0348	1055
	75	$0.0312x + 4.1683$	0.0312	1384
	100	$0.0262x + 4.1457$	0.0262	1734
	125	$0.0157x + 4.1368$	0.0157	2950
Taurin	25	$0.0014x + 4.2937$	0.0014	218
	50	$0.001x + 4.3142$	0.0010	285
	75	$0.0013x + 4.2752$	0.0013	249
	100	$0.0004x + 4.259$	0.0004	852
	125	$0.0016x + 4.2878$	0.0016	195
Control	0	$0.0041x + 4.304$	0.0041	72.19
<i>Doxorubicin</i>	1	$-0.0037x + 4.3688$	-0.0037	-
	5	$-0.0187x + 4.462$	-0.0187	-
	10	$-0.0208x + 4.2854$	-0.0208	-

Note: Cell control slope values = 0.0041

The doubling time of *A. marina* leaf extract indicated a positive correlation with the concentration of the extract, the greater the concentration of the extract the longer the doubling time. The doubling time values of the drug treatment (doxorubicin) could not be obtained, this related with negative value of the slope in the linear regression equation, presumably all the HeLa cells died or no proliferation occurred. Meanwhile, those treatment groups given taurine indicated their doubling time value was higher than the control groups. Therefore, both extract of *A. marina* and taurine were able to interrupt the proliferation of HeLa cervical cancer cells.

In order to elucidate how far the interruption of the *A. marina* extract and taurine on the HeLa cervical cancer cell line, determination of the number of surviving cells then was calculated and could be seen in Table 3 as followed.

The number of surviving HeLa cells varied for both treatment groups and from 24 hours up to 72 hours of observation time. The number of surviving cells decreased as the concentration of extract and taurine increased.

Tabel 3. Effect of *A. marina* and Taurine against average number of surviving cells

Treatment Groups	Concentration (ppm)	Number of living cells (x 1000 cells)		
		24 hours	48 hours	72 hours
Avicennia	25	18.9±1.48 ^a	21.0±1.30 ^a	26.3±0.35 ^a
	50	18.9±0.79 ^a	19.2±0.72 ^a	22.2±0.66 ^b
	75	16.5±0.60 ^{ab}	15.6±0.92 ^b	19.1±0.55 ^c
	100	15.4±0.30 ^b	14.7±1.21 ^b	17.4±0.49 ^d
	125	15.0±1.34 ^b	13.3±0.30 ^b	16.1±0.29 ^d
Taurin	25	21.3±0.30 ^{ab}	21.8±1.42	25.7±0.60 ^{ab}
	50	22.9±1.48 ^a	22.9±1.60	24.2±0.35 ^b
	75	18.3±0.66 ^{bc}	22.1±0.99	23.6±1.80 ^b
	100	15.2±1.99 ^c	21.4±3.08	19.4±1.12 ^c
	125	22.0±1.43 ^{ab}	19.5±1.28	27.8±0.21 ^a

Note: superscript of a, b and c indicated significant different at 5% of LSD

4. DISCUSSION

Based on cytotoxic results carried out for methanol extract of *A. marina* leaves and taurine on *HeLa* cervical cancer cells, both of compounds (*A. marina* extract and taurine) were able to kill the *HeLa* cells indicated by lowering in cell viability (%). This cytotoxic ability was also showed by the destruction of cells by looking at the morphology (Figure 3 a, b, c, and d). *HeLa* cells that underwent apoptosis had a different morphology. Cells shrank as a result of intracellular fluid loss and very low cell density [13]. Living *HeLa* cells are generally polygonal in shape and attached to the matrix. However, it will be separated from the matrix after administration of trypsin.

The IC₅₀ values for *A. marina* leaf extract was 321 ppm, taurine was 603 ppm, and doxorubicin was 12.35 ppm (Table 1). When compared to those of doxorubicin, the IC₅₀ values of the two test compounds were greater. Yet, the standard IC₅₀ value was <1000 ppm, meaning that extract of *A. marina* and taurine belonged to potential cytotoxic compound for the *HeLa* cell lines [14]. Therefore, these two compounds indicated their potential for cytotoxic activity, from which then can be used as anticancer agents [15]

Table 2 shows that the doubling-time values obtained were different at each concentration of the methanol extract of *A. marina* leaf and taurine. In this value for their doubling-time, the slope value of the linear regression equation could be used as a parameter of cell proliferation kinetics. In which the control cells had the slope value of 0.0041. This value became a reference for the treatment groups. If the value of the treatment slope was smaller than the value of the cell control slope, the time required for doubling time was longer [16]. As seen in Table 3, all treatment slope values were lower than the cell control slope values, indicating that the time needed for cells with multiple treatments was longer than for those of the control cells. All the preparation for treated cells to proliferate needed much longer time. These results also indicated that the methanol extract from *A. marina* leaf and taurine had potential as an antiproliferative compound for *HeLa* cervical cancer cells [17].

Based on the treatment with *A. marina* extract it showed a significant difference in the number of living cells in all concentrations. The highest average number of living cells was shown by giving extract concentration of 25 ppm with incubation time of 72 hours, while the lowest average living cells are indicated by extract concentration of 125 ppm with incubation time of 72 hours. In the treatment of taurine, known as a free amino acid, with various concentrations, the average number of living cells differed significantly at the incubation time of 24 hours and 72 hours. These two test compounds indicated that they had cytotoxic activation of *HeLa* cervical cancer cells, presumably this was due to the presence of bioactive compounds contained in the extract of *A. marina*, such as steroid, flavonoids which known also as high levels of antioxidant, therefore, it could inhibit the process of oxidation and proliferation [18].

The cytotoxic activity of *A. marina* plants also showed strong anti-proliferation against L-929 rat fibroblasts and human leukemia cells K562 [19]. Against BT-20 breast cancer cells *A. marina* also showed moderate cytotoxicity [20]. *A. marina* leaf extracts had also proven cytotoxicity to breast cancer cells MCF-7 MDA-MB 231 through apoptosis [21]. *A. marina* as one of mangrove plants has the widest geographical distribution and function, other than as animal feed. Toxicological studies of *A. marina* extracts also indicated that *A. marina* could be developed into anticancer, antibacterial, and anti-arthritis medicinal plants [22].

5. CONCLUSION

- a. *A. marina* leaf extract, and taurine are toxic to *HeLa* cervical cancer cells, evidenced by the percentage of treatment cell viability that is lower than cell control, and the acquisition of IC50 values for all test compounds less than 1000 ppm
- b. *A. marina* leaf extract and taurine can inhibit the proliferation of *HeLa* cervical cancer cells indicating by their doubling-time which much longer than the cell control.
- c. Based on the differences in cytotoxic and anti-proliferative abilities, extract of *A. marina* is more effective as a cytotoxic and anti-proliferative compound against *HeLa* cervical cancer cells compared to a free amino acid taurine

6. ACKNOWLEDGEMENTS

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ROBUST PRINCIPAL COMPONENT TRIMMED CLUSTERING OF INDONESIAN PROVINCES BASED ON HUMAN DEVELOPMENT INDEX INDICATORS

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Abstract

Cluster analysis is a multivariate technique for grouping observations into clusters based on the observed values of several variables for each individual. The existence of outliers in the data can heavily influence standard clustering methods, i.e. the outliers will cause the standard clustering results to be not optimal. Therefore, it is necessary to use a robust clustering method. Trimmed clustering is one of robust clustering methods which is non-hierarchical and known for its good performance in cluster analysis when data contain outlier. The purpose of this study is to classify 34 provinces in Indonesia based on the 2019 Human Development Index (HDI) indicators and see the achievements of human development in each province. The results of this study indicate that there are three optimal clusters. The first cluster consists of 17 provinces with good HDI criteria, the second cluster consists of 9 provinces with a fairly good HDI, and the third cluster consists of 7 provinces with the lowest HDI criteria.

Keyword: robust, trimmed cluster analysis, human development index

2. Introduction

The basic idea of human development is to position humans as the true assets of the nation and create growth in the economic, social, political, cultural and environmental fields that encourage the improvement of people's welfare. Based on this thinking, the main goal of human development is to be able to create an environment that allows people to have a long life, be healthy, and lead a productive life [1].

Achievement of human development is a summary measure of average achievement in key dimensions of human development namely: a long and healthy life, being knowledgeable and have a decent standard of living. The Human Development Index (HDI) is an index used to see human development in a long term. Human development in Indonesia continues to progress. In 2019, Indonesia's HDI reached 71.92. This figure increased by 0.53 points or grew by 0.74 percent compared to 2018 [2]. Based on this enhancement, it is necessary to group Indonesian provinces to find the provinces with the same characteristics and also differences between the groups of provinces. The result can be used as a basis for the government to determine specific policies or programs that suitable for each group.

One of the statistical methods that can be used for grouping objects is cluster analysis. According to *Härdle & Simar* [3], cluster analysis is a multivariate technique which has the main objective to group objects so that diversity within a cluster is minimum while between clusters is maximum. Cluster analysis is based on a distance matrix representing a similarity measure, and the most commonly used measure is Euclidean distances. There is assumption that must be fulfilled when using Euclidean distances for cluster analysis, i.e. all variables are uncorrelated, and this assumption is frequently ignored. An effective procedure that can be used in dealing with the correlation between the variables is by performing a principal component analysis (PCA) before calculating the Euclidean distances, one can see e.g. [4-7] for the use of PCA for clustering in various researches.

PCA is a multivariate technique which aims to reduce the dimensions of data (i.e. the number of the original variables) in order to obtain new variables (i.e. principal components) which are not correlated and contain most of the information of the original variables [8]. Principal components are new variables that are constructed as linear combinations of the original variables. These combinations are done in such a way that these new variables are uncorrelated and most of the information within the initial variables is stored into the first components. Even though the k -dimensional data give k principal components but PCA tries to put maximum possible information in the first ones.

Deviations from theoretical assumptions together with the presence of certain amount of outlying observations are common in many practical statistical applications. In this case, a robust procedure is needed. Robustness in statistics refers to stable behavior of methodology under small changes of data or models. Robustness is a desirable property for general statistical methodology and it has been studied by many authors. Some examples of robustness study can be seen in e.g. [9-12]. A small percentage of outliers can have a large impact on many statistical techniques. This is also the case when applying cluster

analysis methods, where those troubles could lead to unsatisfactory clustering results. Therefore, in the case of the existence of outliers and correlation among variables, performing robust procedures of PCA and cluster analysis are highly recommended.

Let $\mathbf{X} = (X_1 X_2 \dots X_k)'$ has a multivariate distribution with mean vector $\boldsymbol{\mu}$ and covariance matrix $\boldsymbol{\Sigma}$ having eigen vectors $\mathbf{a}_j, j=1, 2, \dots, k$. The principal components are linear combinations of the k original variables which can be expressed as follows [8]:

$$PC_j = a_{1j}X_1 + a_{2j}X_2 + \dots + a_{kj}X_k = \mathbf{a}'_j\mathbf{X}. \quad (1)$$

The covariance matrix $\boldsymbol{\Sigma}$ is known to be very sensitive to the presence of outliers. In many situations, outliers cannot be removed from data for some reasons such as the information they contain and the complicated procedure for outlier detection. To overcome this, a robust estimate of $\boldsymbol{\Sigma}$ is needed namely by replacing the classical sample covariance matrix \mathbf{S} with a robust estimator. The use of robust covariance matrix estimate for the principal component constructing is the same as performing a robust PCA, see e.g. [13] for details.

One of the robust methods for covariance matrices is the Minimum Covariance Determinant (MCD). According to Rousseeuw & Van Driessen [14], the MCD estimator is a pair $(\bar{\mathbf{X}}_{MCD}, \mathbf{S}_{MCD})$, where $\bar{\mathbf{X}}_{MCD}$ is the mean vector and \mathbf{S}_{MCD} is the covariance matrix that minimizes the determinant value of the sample covariance matrix \mathbf{S} in a subsample containing exactly h members of n observations, i.e.

$$\mathbf{S}_{MCD} = \min\{\det(\mathbf{S}_j)\}, \quad j = 1, \dots, \binom{n}{h}. \quad (2)$$

The standard value of h is $[(n+k+1)/2]$ where n is the sample size and k is the number of variables in the data.

For robust cluster analysis, we used trimmed cluster technique called TCLUS (Trimmed CLUSTER) [15-16]. TCLUS is a method in statistical clustering technique which is based on modification of trimmed k -means clustering algorithm [17]. According to García-Escudero *et.al.* [18], the algorithm of TCLUS can be described as follow:

1. Randomly select starting values for the centers \mathbf{m}_j^0 's, the covariace matrices \mathbf{S}_j^0 's and the weights of the grup p_j^0 's for $j = 1, \dots, k$.
2. From the $\boldsymbol{\theta}^l = (p_1^l, \dots, p_k^l, m_1^l, \dots, m_k^l, S_1^l, \dots, S_k^l)$ returned by the previous iterations:
 - Obtain $d_i = D(x_i, \boldsymbol{\theta}^l)$ for the observation $\{x_1, \dots, x_n\}$ and keep the set H having the $[n(1 - \alpha)]$ observations with largest d_i 's where $D(x_i, \boldsymbol{\theta}^l) = \max\{D_1(x_i, \boldsymbol{\theta}^l), \dots, D_k(x_i, \boldsymbol{\theta}^l)\}$ and $D_j(x_i, \boldsymbol{\theta}^l) = \pi_j f(x; \boldsymbol{\mu}_j, \boldsymbol{\Sigma}_j)$ with π_j - the

group weight and $f(x; \boldsymbol{\mu}_j, \boldsymbol{\Sigma}_j)$ is the probability density function (p.d.f.) of k -variate normal distribution.

- Split H into $H = \{H_1, \dots, H_k\}$ with $H_j = \{x_i \in H : D_j(x_i, \theta^l) = D(x_i, \theta^l)\}$.
 - Obtain the number of data points n_j in H_j and their sample mean and sample covariance matrix, \mathbf{m}_j and \mathbf{S}_j , $j = 1, \dots, k$.
 - Consider the singular-value decomposition of $\mathbf{S}_j = \mathbf{U}_j' \mathbf{D}_j \mathbf{U}_j$ where \mathbf{U}_j is a orthogonal matrix and $\mathbf{D}_j = \text{diag}(\Lambda_j)$ is a diagonal matrix (with diagonal elements given by the vector Λ). If the full vector of eigenvalues $\Lambda = (\Lambda_1, \dots, \Lambda_k)$ does not satisfy the eigenvalues-ratio (ER) restriction, obtain (for instance) through Dykstra's algorithm [19-21] a new vector $\tilde{\Lambda} = (\tilde{\Lambda}_1, \dots, \tilde{\Lambda}_k)$ obeying the eigen restriction and with $\|\tilde{\Lambda} - \Lambda^{-1}\|^2$ being as smaller as possible. (Λ^{-1} denotes the vector made up by the inverse of the elements of the vector Λ). Notice that the eigen restriction for Λ corresponds exactly to the same eigen restriction applied to Λ^{-1} .
 - Update θ^{l+1} by using:
 - $\mathbf{p}_j^{l+1} \leftarrow n_j/[n(1 - \alpha)]$,
 - $\mathbf{m}_j^{l+1} \leftarrow \mathbf{m}_j$,
 - $\mathbf{S}_j^{l+1} \leftarrow \mathbf{U}_j' \tilde{\mathbf{D}}_j \mathbf{U}_j$ and $\tilde{\mathbf{D}}_j = \text{diag}(\tilde{\Lambda}_j)^{-1}$
3. Perform F iterations of the process described in step 2 (moderate values for F are usually enough) and compute the evaluation function $L(\theta^F; P_n)$ using $\theta \mapsto L(\theta, P) := E_p[\sum_{j=1}^k z_j(\cdot; \theta) \log D_j]$,
 4. Start from step 1 several times, keeping the solutions leading to minimal values of $L(\theta^F, P_n)$ and fully iterate them to choose the best one.

For more details and discussion on the trimmed cluster algorithm, one can see [15-18].

3. Methodology

The 2019 HDI data published by Central Bureau of Statistics of Indonesia consists of $n=34$ provinces. The variables used in the analysis are: life expectancy of birth in 2019 (LE), expected years of schooling of 7-year-old children (EYS), mean years of schooling of the population aged 25 years and over (AYS), and average spending per capita adjusted at the provincial level (ASC). The indicator variables used to compose the HDI index in Indonesia were adopted from the HDI indicators recognized by United Nations Development Program (UNDP).

The analysis was performed using R software, the analysis procedure can be described as follow:

- HDI data screening to detect the presence of outliers by using Mahalanobis distance $D(\mathbf{x}_i)_{MCD} = \sqrt{(\mathbf{x}_i - \bar{\mathbf{x}}_{MCD})\mathbf{S}_{MCD}^{-1}(\mathbf{x}_i - \bar{\mathbf{x}}_{MCD})}$ for $i=1, 2, \dots, 34$;
- checking the correlation between variables LE, EYS, AYS and ASC;
- conducting robust principal component analysis using covariance matrix \mathbf{S}_{MCD} ;
- performing robust clustering based on the robust principal component scores obtained using TCLUS;T;
- determining the optimal clusters of the provinces.

4. Result and Discussion

The first step in this research is assessing the presence of outliers in the data so that the analysis results obtained are correct. Outlier detection from the HDI data in 2019 is based on the robust squared Mahalanobis distance for 34 provinces in Indonesia as follows.

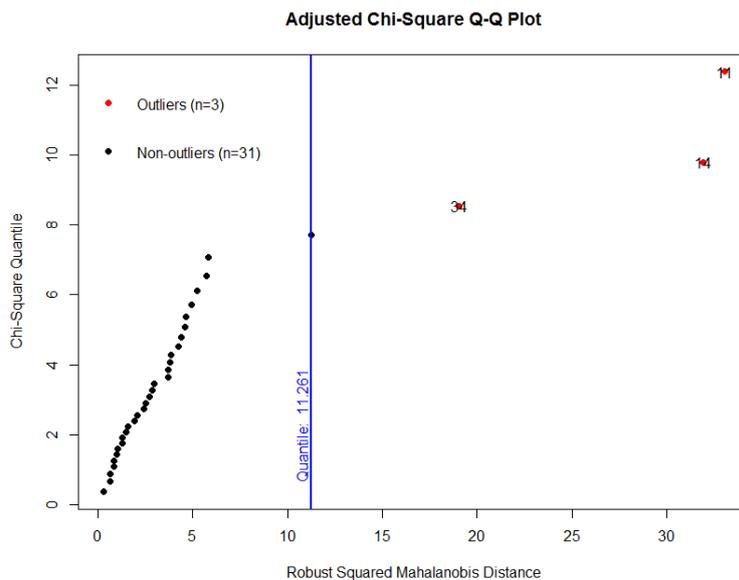


Figure 1. Outlier detection

In Figure 1, three provinces were identified as outliers. The suspected provinces are presented in the following table.

Table 1. List of Outliers

Province	LE	EYS	AYS	ASC
DKI Jakarta	72.79	12.97	11.06	18527
D.I Yogyakarta	74.92	15.58	9.38	14394
Papua	65.65	11.05	6.65	7336

In Table 1, DKI Jakarta and D.I Yogyakarta have very high values of the HDI indicators while Papua has the lowest HDI indicators in 2019. Furthermore, checking the correlation between variables is also considered important so that the characteristics of the clusters that are formed are optimal.

The following is the table of correlation matrix of data which shows correlation coefficients between variables. Based on Table 2, it can be seen that there are fairly small correlations between variables, which is between 0.2 and 0.5. To obtain independent variables for the cluster analysis, principal component analysis was performed.

Table 2. Correlation Matrix

	LE	EYS	AYS	ASC
LE	1.00000	0.25544	0.40547	0.58957
EYS	0.25544	1.00000	0.47532	0.17042
AYS	0.40547	0.47532	1.00000	0.58356
ASC	0.58957	0.17042	0.58356	1.00000

Because of the correlation and outlier problems, we used a robust method when performing PCA by using MCD mean vector \bar{X}_{MCD} and covariance matrix S_{MCD} .

Determining the number of clusters to be formed can be done by looking at how the data spread and cluster. For that we looked at the scatter plots of the first and second principal components obtained from PCA. To ensure that the scatter plots of the components contain sufficient information to represent the original variables, we examined the proportions of their variances. The variance of each principal component (PC) is equivalent to the eigenvalue of the covariance matrix S_{MCD} . We obtain the eigen values of covariance matrix S_{MCD} were: 0.78220, 0.75539, 0.26012 and 0.18735, the corresponding proportion of variance of each PC is shown in Table 3.

Table 3. The proportion of variance of principal components

Eigen Value	Variance proportion	Cumulative variance proportion
0.78220	0.39404	0.39404
0.75539	0.38053	0.77457
0.26012	0.13104	0.90561
0.18735	0.09438	0.99999

The variance of first PC (PC1) is 0.78220 which explains 39.40% of total variance, the variance of the second PC (PC2) is 0.75539 and explains 38.05% of total variance. Thus, PC1 and PC2 are deemed sufficient to represent the data structure with a cumulative variance of 77.45%. However, this research requires 100% information to represent the data structure in the next analysis so that the results obtained are optimal. So this study uses all principal component scores, namely the PC1-PC4 score. The following is the plotting of the principal component scores (Figure 2) to see the spread of the data based on the first and the second principal component scores. Based on the spread of the data we suspected that they are divided into three clusters.

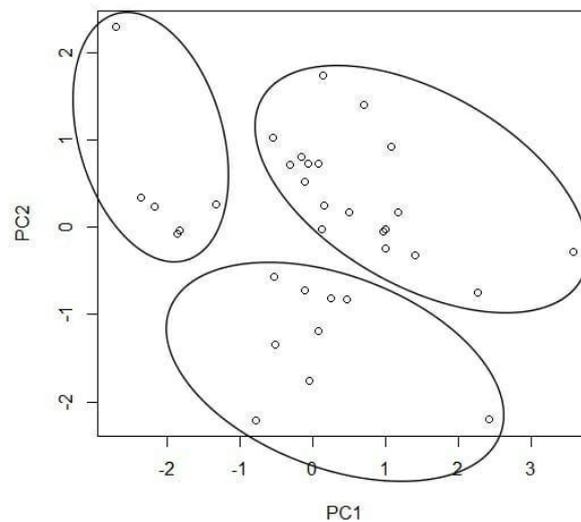


Figure 2. Principal Component Plot

Furthermore, for cluster analysis, this study also uses a robust method, namely trimmed clustering. The robust cluster analysis used is based on the principal component scores that have been obtained. According Md.Jedi & Adnan [17], most complex problem when applying non-hierarchical cluster analysis is to choose the number of clusters, k . It is certain that we must choose the initial number of cluster, but we did not really know what the best number of clusters that is supposed to be in the data. The same principal also applies to the trimming size, where we did not know exactly the true outlying level. Garcia-Escudero *et.al.* [18] introduced some classification trimmed likelihood curves as useful curve for choosing the number of clusters k . The k -th trimmed likelihood function is defined as:

$$\alpha \mapsto \ell_c^{\Pi}(\alpha, k) \text{ for } \alpha \in [0,1)$$

with $\ell_c^\Pi(\alpha, k) = \sum_{j=1}^k \sum_{i \in R_j} \log f(x_i; \mu_j, \Sigma_j)$. This curve function is allowed to measure $\Delta_c^\Pi(\alpha, k) = \ell_c^\Pi(\alpha, k + 1) - \ell_c^\Pi(\alpha, k)$ where $\Delta_c^\Pi(\alpha, k)$ should be close to 0. Figure 3 shows the classification trimmed likelihood curve $\Delta_c^\Pi(\alpha, k)$ when $k=1,2,3,4$ and α range is $[0, 0.2]$ and $c=50$. Because in Figure 3 it can be seen that no significant increase occurs when increasing k from 3 to 4 and it is supported by the results of the principal component plot in Figure 2, then for this data case, the optimal number of clusters will be selected as 3 clusters with $\alpha = 0.05$, which means 5 % of trimmed data is data that is not part of the cluster formed.

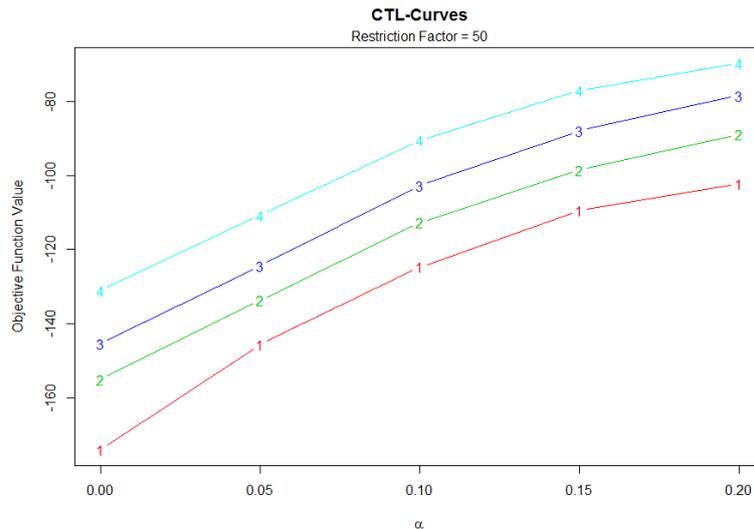


Figure 3. Classification trimmed likelihood curves $\ell_c^\Pi(\alpha, k)$ when $k=1,2,3,4$ and α range in $[0, 0.2]$ and $c=50$

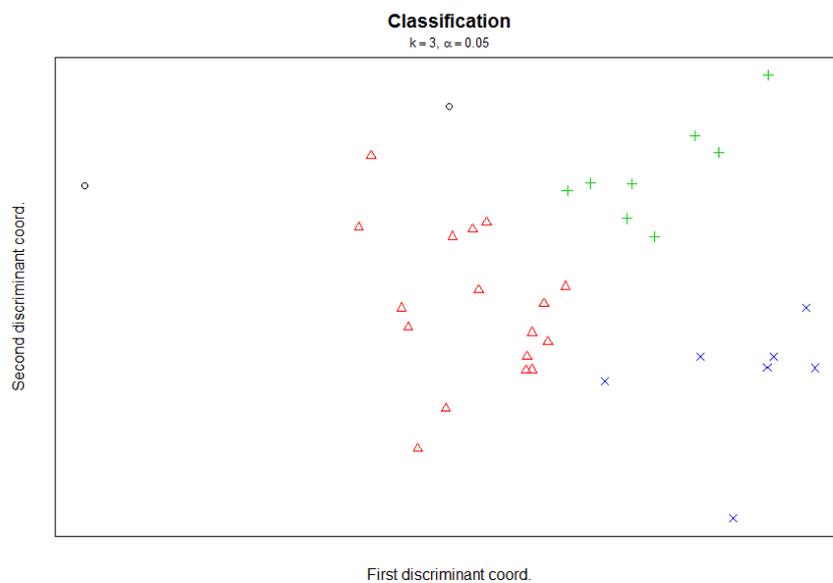


Figure 4. Classification Trimmed Plot

After trimmed cluster analysis on the principal component scores, two outliers namely DKI Jakarta and D.I Yogyakarta, were considered to have their own clusters. While the members of the three clusters are presented in Table 4.

Table 4. Cluster Members

Cluster	Provinces
1	Riau, Jambi, South Sumatra, Lampung, Bangka Belitung Island, Riau Island, West Java, Central Java, East Java, Banten, Bali, Central Kalimantan, South Kalimantan, East Kalimantan, North Kalimantan, North Sulawesi, South Sulawesi
2	Aceh, North Sumatra, West Sumatra, Bengkulu, Central Sulawesi, Southeast Sulawesi, Maluku, North Maluku
3	NTB, NTT, West Kalimantan, Gorontalo, West Sulawesi, West Papua, Papua

Table 5. Cluster Centre ($\bar{X}_{(x)k}$)

Cluster	LE	EYS	AYS	ASC
1	71.178	12.825	8.568	11656.1
2	68.817	13.664	9.094	9727.6
3	66.856	12.665	7.377	8890.7

Cluster 1 is a group of provinces with life expectancy of birth in 2019 (LE) of approximately 71.2 years, the expected years of schooling of 7-year-old children (EYS) of approximately 12.8 years, mean years of schooling of the population aged 25 years and over (AYS) of 8.6 years, and average spending per capita adjusted at the provincial level (ASC) of IDR 11656.1. Cluster 2 is a group of provinces with LE approximately of 68.8 years, EYS of approximately 13.6 years, AYS of about 9 years and ASC of IDR 9727.6. Cluster 3 is a group of provinces with LE of about 66.8 years, EYS of about 12.6 years, AYS of about 7.4 years and ASC of IDR 8890.7.

To determine the variables that must be paid more attention to in each cluster so that the HDI achievement in the following year can be increased, it is necessary to carry out an analysis of the description in each cluster by calculating the average value of each indicator variable forming the 2019 HDI, namely LE ($\bar{X}_{LE} = 69.64$), EYS ($\bar{X}_{EYS} = 13.01$), AYS ($\bar{X}_{AYS} = 8.44$), ASC ($\bar{X}_{ASC} = 10569$). Then these values are compared with the cluster center ($\bar{X}_{(x)k}$) shown in Table 5.

If we get $\bar{X}_{(x)k} \leq \bar{X}_x$ where x is the observed variables (LE, EYS, AYS, ASC), it can be interpreted that the average value of the variables in the cluster is low or

classified as "Bad" so that the observed variable must be further increased in each province. Conversely, if we get $\bar{X}_{(x)k} \geq \bar{X}_x$ then the average value of the variables in the cluster can be said as "Good" in the HDI forming indicators. Details are presented in the following table:

Table 6. Cluster Characteristics

Cluster	LE	EYS	AYS	ASC
1	Good	Bad	Good	Good
2	Bad	Good	Good	Bad
3	Bad	Bad	Bad	Bad

Table 6 shows that the members in Cluster 1 have fairly good HDI indicator characteristics on life expectancy of birth in 2019, mean years of schooling of the population aged 25 years and over, and average spending per capita adjusted at the provincial level, and obtained a low average score for expected years of schooling of 7-year- old children.

Cluster 2 members have fairly good HDI indicator characteristics on expected years of schooling of 7-year- old children, and mean years of schooling of the population aged 25 years and over, and obtained a low average score for life expectancy of birth in 2019 and average spending per capita adjusted at the provincial level.

Furthermore, members in cluster 3 are provinces that have very low HDI indicator characteristics. This is because the average of observed variables LE, EYS, AYS, ASC in the cluster center less than the actual average value. Thus, the provinces in Cluster 3 need more attention so that life expectancy of babies born in 2019, expected years of schooling of 7-year-old children, mean years of schooling of the population aged 25 years and over, and average spending per capita adjusted at the provincial level can be increased.

5. Conclusion

In this paper, we applied the robust principal component trimmed clustering for grouping Indonesian provinces based on HDI indicators. Based on the cluster analysis on the data using robust principal component trimmed clustering, the optimum number of clusters for the Indonesian provinces based on HDI indicators is three clusters.

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MATRIKS ATAS RING DERET PANGKAT TERGENERALISASI MIRING

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Abstrak

Misalkan R adalah ring dengan elemen satuan, (S, \leq) monoid terurut tegas dan $\omega: S \rightarrow \text{End}(R)$ suatu homomorfisma monoid. Dibentuk himpunan $R[[S, \leq, \omega]]$, yaitu himpunan semua fungsi-fungsi dari S ke R dengan $\text{supp}(f)$ bersifat Artin dan *narrow*. Terhadap operasi penjumlahan fungsi dan pergandaan konvolusi, $R[[S, \leq]]$ merupakan ring, yang selanjutnya disebut dengan Ring Deret Pangkat Tergeneralisasi Miring (RDPTM). Pada makalah ini, akan dikonstruksi himpunan semua matriks atas RDPTM $R[[S, \leq, \omega]]$. Selanjutnya, akan ditunjukkan bahwa himpunan matriks ini merupakan ring terhadap operasi penjumlahan dan pergandaan matriks. Lebih lanjut, akan dikonstruksi ideal dari ring matriks atas RDPTM serta dikaji beberapa sifatnya.

Kata Kunci : Artin, *narrow*, matriks atas ring, monoid terurut tegas, ring deret pangkat tergeneralisasi miring.

Abstract

Let R be a ring with unit elements, (S, \leq) strictly ordered monoids, and $\omega: S \rightarrow \text{End}(R)$ a monoid homomorphism. Formed $R[[S, \leq, \omega]]$, which is a set of all functions from S to R with $\text{supp}(f)$ are Artin and *narrow*. With the operation of the sum of functions and convolution multiplication, $R[[S, \leq, \omega]]$ is a ring, from now on referred to as the Skew Generalized Power Series Ring (SGPSR). In this paper, the set of all matrices over SGPSR $R[[S, \leq, \omega]]$ will be constructed. Furthermore, it will be shown that this set is a ring with the addition and multiplication matrix operations. Moreover, we will construct the ideal of ring matrix over SGPSR and investigate this ideal's properties.

Keywords: Artinian, *narrow*, matrices over a ring, strictly ordered monoid, skew generalized power series ring



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1. PENDAHULUAN

Telah diketahui bahwa suatu matriks adalah susunan bilangan-bilangan dalam baris dan kolom yang berbentuk persegi panjang yang diapit oleh kurung siku atau kurung biasa [1]. Bilangan-bilangan ini biasa disebut entri-entri. Secara umum entri-entri suatu matriks merupakan anggota dari suatu lapangan (field), seperti himpunan bilangan real \mathbb{R} . Lebih lanjut, matriks ini disebut matriks atas lapangan. Berdasarkan

fakta bahwa struktur ring lebih umum dari lapangan, suatu matriks atas lapangan dapat digeneralisasi menjadi matriks atas ring [2]. Ring didefinisikan sebagai suatu himpunan tak kosong yang dilengkapi dua operasi biner dan memenuhi beberapa aksioma tertentu [3]. Salah satu contoh ring yaitu, Ring Deret Pangkat Tergeneralisasi (RDPT) $R[[S]]$ yang dikonstruksi oleh Ribenboim pada tahun 1990 [4]. Ring ini merupakan perumuman dari ring semigrup [5], ring polinomial dan ring deret pangkat formal [6]. Ribenboim mengkonstruksi RDPT $R[[S]]$ dengan cara menerapkan konsep himpunan terurut parsial dan memperlemah syarat $\text{supp}(f)$ berhingga pada ring polinomial $R[X]$ dan ring semigrup $R[S]$ menjadi $\text{supp}(f)$ yang bersifat Artin dan narrow.

Relasi urutan parsial adalah suatu relasi biner " \leq " pada himpunan tak kosong S yang memenuhi sifat refleksif, anti simetris dan transitif [7]. Himpunan tak kosong S yang dilengkapi dengan suatu urutan parsial disebut himpunan terurut parsial (partially ordered set) dan dinotasikan dengan (S, \leq) . Himpunan terurut parsial (S, \leq) dikatakan Artin, jika setiap barisan terurut tegas dari elemen S berhingga. Himpunan terurut (S, \leq) dikatakan narrow jika setiap subhimpunan S yang terurut trivial berhingga [8]. Dalam perkembangannya, penelitian terkait sifat-sifat yang berlaku pada $R[[S]]$ telah dikaji oleh Ribenboim [9],[10],[11],[12],[13],[14]. Di sisi lain, Varadarajan [15] menkonstruksi Modul Deret Pangkat Tergeneralisasi (MDPT) $M[[S]]$, yang merupakan modul atas $R[[S]]$. Selain itu, Varadarajan [16] memberikan syarat perlu dan cukup $M[[S]]$ merupakan modul Noether. Di pihak lain, Faisal, dkk. [17] mengkaji karakterisasi $M[[S]]$ merupakan modul $T[[S]]$ -Noether. Hal ini dilakukan dengan cara memperumum syarat perlu dan cukup modul polinomial $M[X]$ merupakan modul $T[X]$ -Noether [18], serta menerapkan hubungan antar modul yang hampir dibangun secara hingga, modul hampir Noether dan modul T -Noether [19].

Pada tahun 2008, Mazurek dan Ziembowski [20] memperumum struktur $R[[S]]$ dengan cara menambahkan suatu homomorfisma monoid $\omega: S \rightarrow \text{End}(R)$ ke dalam operasi pergandaan konvolusi yang ada pada $R[[S]]$. Ring ini selanjutnya disebut dengan Ring Deret Pangkat Tergeneralisasi Miring (RDPTM) dan dinotasikan dengan $R[[S, \leq, \omega]]$ atau disingkat $R[[S, \omega]]$. Selanjutnya, sifat-sifat terkait $R[[S, \omega]]$ telah dikaji oleh Mazurek, dkk. [21],[22],[23],[24],[25]. Hasil penelitian lain terkait struktur $R[[S, \omega]]$ juga telah dikaji oleh Faisal, dkk. [26],[27],[28],[29],[30],[31]. Sejauh ini, $R[[S, \omega]]$ merupakan struktur ring yang paling umum, yaitu untuk ring R , monoid S dan ω tertentu, $R[[S, \omega]]$ merupakan RDPT $R[[S]]$, ring semigrup $R[S]$, ring deret pangkat $R[[X]]$ dan ring polinomial $R[X]$. Hal ini memberikan motivasi untuk mengkaji sifat-sifat serta struktur aljabar lain yang berkaitan dengan $R[[S, \omega]]$, yang hasilnya nanti akan berakibat langsung pada struktur ring yang lebih khusus dari $R[[S, \omega]]$. Oleh karena itu, pada makalah ini akan dikonstruksi himpunan semua matriks atas $R[[S, \omega]]$, serta akan dibuktikan apakah matriks atas $R[[S, \omega]]$ ini merupakan suatu ring. Selain itu, akan dikonstruksi ideal dari ring matriks atas RDPTM serta dikaji sifat-sifatnya.

2. METODE PENELITIAN

Metode Metode yang digunakan pada makalah ini adalah studi literatur berupa buku-buku dan jurnal-jurnal ilmiah, khususnya yang berkaitan dengan konsep matriks

atas ring, himpunan terurut parsial, sifat Artin dan narrow, ring deret pangkat tergeneralisasi (RDPT) dan ring deret pangkat tergeneralisasi miring (RDPTM). Langkah-langkah yang digunakan yaitu, mengkonstruksi matriks atas RDPTM, membuktikan himpunan matriks atas RDPTM terhadap operasi penjumlahan dan perkalian matriks merupakan ring, dan mengkonstruksi ideal ring matriks atas RDPTM, serta mengakaji sifat-sifatnya.

3. HASIL DAN PEMBAHASAN

Penulisan Pada bagian ini akan ditunjukkan himpunan semua matriks atas RDPTM merupakan ring. Sebelumnya, akan diberikan definisi dari RDPTM $R[[S, \omega]]$ yang telah dikonstruksi oleh Mazurek dan Ziemkowski [20].

Diberikan sebarang ring komutatif R dengan elemen satuan, monoid terurut tegas (S, \leq) dan homomorfisma monoid $\omega: S \rightarrow \text{End}(R)$. Dibentuk himpunan semua fungsi dari S ke R , yang dinotasikan dengan R^S . Selanjutnya, didefinisikan himpunan

$R[[S, \omega]] = \{f \in R^S \mid \text{supp}(f) \text{ Artin dan narrow}\}$,
dengan $\text{supp}(f) = \{s \in S \mid f(s) \neq 0\}$. Himpunan $R[[S, \omega]]$ yang dilengkapi dengan operasi penjumlahan yang didefinisikan oleh:

$$(f + g)(s) = f(s) + g(s), \quad (1)$$

dan operasi pergandaan konvolusi yang didefinisikan oleh:

$$(fg)(s) = \sum_{(t,u) \in \chi_s(f,g)} f(t)\omega_t(g(u)), \quad (2)$$

untuk setiap $s \in S$ dan $f, g \in R[[S, \omega]]$, dengan himpunan $\chi_s(f, g) = \{(t, u) \in S^2 \mid f(t) \neq 0, g(u) \neq 0 \text{ dan } t + u = s\}$ berhingga, merupakan suatu ring. Ring ini selanjutnya disebut ring deret pangkat tergeneralisasi miring (RDPTM).

Untuk selanjutnya, matriks $n \times n$ atas ring R dinotasikan dengan A_n , matriks $n \times n$ atas ring polinomial $R[X]$ dinotasikan dengan $A_n[X]$, matriks $n \times n$ atas ring deret pangkat $R[[X]]$ dinotasikan dengan $A_n[[X]]$, matriks $n \times n$ atas ring RDPT $R[[S]]$ dinotasikan dengan $A_n[[S]]$, dan matriks $n \times n$ atas RDPTM $R[[S, \omega]]$ dinotasikan dengan $A_n[[S, \omega]]$. Lebih lanjut, himpunan semua matriks berukuran $n \times n$ atas RDPTM dinotasikan oleh

$$M_n(R[[S, \omega]]) = \{A_n[[S, \omega]] = [f_{ij}] \mid f_{ij} \in R[[S, \omega]]; i, j = 1, 2, \dots, n\}.$$

Proposisi 3.1. Jika diberikan ring komutatif R dengan elemen satuan, monoid terurut tegas (S, \leq) , dan homomorfisma monoid $\omega: S \rightarrow \text{End}(R)$, maka himpunan matriks atas RDPTM $M_n(R[[S, \omega]])$ terhadap operasi penjumlahan dan pergandaan matriks merupakan ring.

Bukti. Pertama akan ditunjukkan $M_n(R[[S, \omega]])$ terhadap operasi penjumlahan matriks merupakan grup komutatif (grup Abel).

(i) Untuk sebarang $A_n[[S, \omega]], B_n[[S, \omega]] \in M_n(R[[S, \omega]])$, $A_n[[S, \omega]] + B_n[[S, \omega]] = [f_{ij}] + [g_{ij}] = [f_{ij} + g_{ij}]$. Karena $f_{ij} + g_{ij} \in R[[S, \omega]]$ untuk setiap $f_{ij}, g_{ij} \in R[[S, \omega]]$, maka $A_n[[S, \omega]] + B_n[[S, \omega]] \in M_n(R[[S, \omega]])$.

Dengan kata lain, $M_n(R[[S, \omega]])$ tertutup terhadap operasi penjumlahan matriks.

(ii) Untuk sebarang $A_n[[S, \omega]], B_n[[S, \omega]], C_n[[S, \omega]] \in M_n(R[[S, \omega]])$, berlaku

$$\begin{aligned} (A_n[[S, \omega]] + B_n[[S, \omega]]) + C_n[[S, \omega]] &= ([f_{ij}] + [g_{ij}]) + [h_{ij}] \\ &= [f_{ij} + g_{ij}] + [h_{ij}] \\ &= [(f_{ij} + g_{ij}) + h_{ij}] \\ &= [f_{ij} + (g_{ij} + h_{ij})] \\ &= [f_{ij}] + [g_{ij} + h_{ij}] \\ &= [f_{ij}] + ([g_{ij}] + [h_{ij}]) \\ &= A_n[[S, \omega]] + (B_n[[S, \omega]] + C_n[[S, \omega]]). \end{aligned}$$

Jadi terbukti operasi penjumlahan matriks pada $M_n(R[[S, \omega]])$ bersifat asosiatif.

(iii) Didefinisikan matriks $O_n[[S, \omega]] = [0_{ij}]$, dengan $0_{ij} = 0 \in R[[S, \omega]]$ untuk setiap $i, j = 1, 2, \dots, n$. Jelas bahwa $O_n[[S, \omega]] \in M_n(R[[S, \omega]])$, karena $0: S \rightarrow R$ merupakan elemen identitas terhadap operasi penjumlahan di $R[[S, \omega]]$. Selanjutnya, untuk setiap $A_n[[S, \omega]] \in M_n(R[[S, \omega]])$ berlaku

$$\begin{aligned} A_n[[S, \omega]] + O_n[[S, \omega]] &= [f_{ij}] + [0_{ij}] \\ &= [f_{ij} + 0_{ij}] \\ &= [f_{ij} + 0] \\ &= [f_{ij}] \\ &= A_n[[S, \omega]]. \end{aligned}$$

Jadi terbukti, terdapat elemen identitas di $M_n(R[[S, \omega]])$

(iv) Untuk sebarang $A_n[[S, \omega]] \in M_n(R[[S, \omega]])$, didefinisikan $-A_n[[S, \omega]] = [-f_{ij}]$, dengan $-f_{ij}$ adalah invers penjumlahan dari f_{ij} di $R[[S, \omega]]$. Oleh karena itu, jelas bahwa, $-f_{ij} \in R[[S, \omega]]$. Dengan kata lain, $-A_n[[S, \omega]] \in M_n(R[[S, \omega]])$. Lebih lanjut, berlaku

$$\begin{aligned} A_n[[S, \omega]] + (-A_n[[S, \omega]]) &= [f_{ij}] + [-f_{ij}] \\ &= [f_{ij} + (-f_{ij})] \\ &= [0] = [0_{ij}] \\ &= O_n[[S, \omega]]. \end{aligned}$$

Jadi terbukti, setiap elemen di $M_n(R[[S, \omega]])$ mempunyai invers.

(v) Untuk sebarang $A_n[[S, \omega]], B_n[[S, \omega]] \in M_n(R[[S, \omega]])$, berlaku

$$A_n[[S, \omega]] + B_n[[S, \omega]] = [f_{ij}] + [g_{ij}]$$

$$\begin{aligned}
&= [f_{ij} + g_{ij}] \\
&= [g_{ij} + f_{ij}] \\
&= [g_{ij}] + [f_{ij}] \\
&= B_n[[S, \omega]] + A_n[[S, \omega]].
\end{aligned}$$

Jadi terbukti operasi penjumlahan matriks pada $M_n(R[[S, \omega]])$ bersifat komutatif.

Dari (i) - (v), terbukti bahwa $M_n(R[[S, \omega]])$ terhadap operasi penjumlahan matriks merupakan grup komutatif (grup Abel). Selanjutnya, akan ditunjukkan $M_n(R[[S, \omega]])$ terhadap operasi perkalian matriks merupakan semigrup.

a) Untuk sebarang $A_n[[S, \omega]], B_n[[S, \omega]] \in M_n(R[[S, \omega]])$, $A_n[[S, \omega]]B_n[[S, \omega]] = [f_{ij}][g_{ij}] = [h_{ij}]$, dengan $h_{ij} = \sum_{k=1}^n f_{ik}g_{kj}$. Karena $R[[S, \omega]]$ tertutup terhadap operasi penjumlahan dan perkalian, maka jelas $f_{ik}g_{kj} \in R[[S, \omega]]$ dan $\sum_{k=1}^n f_{ik}g_{kj} \in R[[S, \omega]]$. Dengan kata lain, $h_{ij} \in R[[S, \omega]]$ dan berakibat $A_n[[S, \omega]]B_n[[S, \omega]] \in M_n(R[[S, \omega]])$. Jadi, terbukti $M_n(R[[S, \omega]])$ tertutup terhadap operasi perkalian matriks.

b) Untuk sebarang $A_n[[S, \omega]], B_n[[S, \omega]], C_n[[S, \omega]] \in M_n(R[[S, \omega]])$, berlaku $(A_n[[S, \omega]]B_n[[S, \omega]])C_n[[S, \omega]] = ([f_{ij}][g_{ij}])[h_{ij}]$

$$\begin{aligned}
&= [\alpha_{ij}][h_{ij}] && ; \alpha_{ij} = \sum_{k=1}^n f_{ik}g_{kj} \\
&= [\gamma_{ij}] && ; \gamma_{ij} = \sum_{m=1}^n \alpha_{im}h_{mj}
\end{aligned}$$

$$\begin{aligned}
\text{Oleh karena itu, diperoleh } & \gamma_{ij} = \sum_{m=1}^n \alpha_{im}h_{mj} \\
&= \sum_{m=1}^n (\sum_{k=1}^n f_{ik}g_{km})h_{mj} \\
&= \sum_{k=1}^n f_{ik} (\sum_{m=1}^n g_{km}h_{mj}) \\
&= \sum_{k=1}^n f_{ik}\delta_{kj} && ; \delta_{kj} = \sum_{m=1}^n g_{km}h_{mj} = \mu_{ij} \\
&&& ; \mu_{ij} = \sum_{k=1}^n f_{ik}\delta_{kj}
\end{aligned}$$

Dengan kata lain,

$$\begin{aligned}
(A_n[[S, \omega]]B_n[[S, \omega]])C_n[[S, \omega]] &= ([f_{ij}][g_{ij}])[h_{ij}] \\
&= [\alpha_{ij}][h_{ij}] && ; \alpha_{ij} = \sum_{k=1}^n f_{ik}g_{kj} \\
&= [\gamma_{ij}] && ; \gamma_{ij} = \sum_{m=1}^n \alpha_{im}h_{mj} \\
&= [\mu_{ij}] && ; \mu_{ij} = \sum_{k=1}^n f_{ik}\delta_{kj} \\
&= [f_{ij}][\delta_{ij}] && ; \delta_{ij} = \sum_{m=1}^n g_{im}h_{mj}
\end{aligned}$$

$$\begin{aligned}
&= [f_{ij}]([g_{ij}][h_{ij}]) \\
&= A_n[[S, \omega]](B_n[[S, \omega]]C_n[[S, \omega]])
\end{aligned}$$

Jadi terbukti operasi perkalian matriks pada $M_n(R[[S, \omega]])$ bersifat asosiatif.

Dari a) dan b), terbukti bahwa $M_n(R[[S, \omega]])$ terhadap operasi perkalian matriks merupakan semigrup. Selanjutnya, akan ditunjukkan berlaku hukum distributif kiri dan kanan pada operasi penjumlahan dan perkalian matriks pada $M_n(R[[S, \omega]])$.

1) Untuk sebarang $A_n[[S, \omega]], B_n[[S, \omega]], C_n[[S, \omega]] \in M_n(R[[S, \omega]])$, berlaku

$$\begin{aligned}
A_n[[S, \omega]](B_n[[S, \omega]] + C_n[[S, \omega]]) &= [f_{ij}]([g_{ij}] + [h_{ij}]) \\
&= [f_{ij}][\alpha_{ij}] && ; \alpha_{ij} = g_{ij} + h_{ij} \\
&= [\gamma_{ij}] && ; \gamma_{ij} = \sum_{k=1}^n f_{ik}\alpha_{kj}
\end{aligned}$$

Oleh karena itu, diperoleh

$$\begin{aligned}
\gamma_{ij} &= \sum_{k=1}^n f_{ik}\alpha_{kj} \\
&= \sum_{k=1}^n f_{ik}(g_{kj} + h_{kj}) \\
&= \sum_{k=1}^n (f_{ik}g_{kj} + f_{ik}h_{kj}) \\
&= \sum_{k=1}^n f_{ik}g_{kj} + \sum_{k=1}^n f_{ik}h_{kj} \\
&= \delta_{ij} + \mu_{ij} && ; \delta_{ij} = \sum_{k=1}^n f_{ik}g_{kj} \text{ dan } \mu_{ij} = \sum_{k=1}^n f_{ik}h_{kj}
\end{aligned}$$

Dengan kata lain,

$$\begin{aligned}
A_n[[S, \omega]](B_n[[S, \omega]] + C_n[[S, \omega]]) &= [f_{ij}]([g_{ij}] + [h_{ij}]) \\
&= [f_{ij}][\alpha_{ij}] && ; \alpha_{ij} = g_{ij} + h_{ij} \\
&= [\gamma_{ij}] && ; \gamma_{ij} = \sum_{k=1}^n f_{ik}\alpha_{kj} \\
&= [\delta_{ij} + \mu_{ij}] && ; \delta_{ij} = \sum_{k=1}^n f_{ik}g_{kj} \text{ dan} \\
&&& \mu_{ij} = \sum_{k=1}^n f_{ik}h_{kj} \\
&= [\delta_{ij}] + [\mu_{ij}] \\
&= [f_{ij}][g_{ij}] + [f_{ij}][h_{ij}] \\
&= A_n[[S, \omega]]B_n[[S, \omega]] + A_n[[S, \omega]]C_n[[S, \omega]].
\end{aligned}$$

2) Untuk sebarang $A_n[[S, \omega]], B_n[[S, \omega]], C_n[[S, \omega]] \in M_n(R[[S, \omega]])$, berlaku

$$\begin{aligned}
(A_n[[S, \omega]] + B_n[[S, \omega]])C_n[[S, \omega]] &= ([f_{ij}] + [g_{ij}])[h_{ij}] \\
&= [\alpha_{ij}][h_{ij}] && ; \alpha_{ij} = f_{ij} + g_{ij} \\
&= [\gamma_{ij}] && ; \gamma_{ij} = \sum_{k=1}^n \alpha_{ik}h_{kj}
\end{aligned}$$

$$\begin{aligned}
\text{Oleh karena itu, diperoleh } \gamma_{ij} &= \sum_{k=1}^n \alpha_{ik} h_{kj} \\
&= \sum_{k=1}^n (f_{ik} + g_{ik}) h_{kj} \\
&= \sum_{k=1}^n (f_{ik} h_{kj} + g_{ik} h_{kj}) \\
&= \sum_{k=1}^n f_{ik} h_{kj} + \sum_{k=1}^n g_{ik} h_{kj} \\
&= \delta_{ij} + \mu_{ij} \quad ; \delta_{ij} = \sum_{k=1}^n f_{ik} h_{kj} \text{ dan } \mu_{ij} = \sum_{k=1}^n g_{ik} h_{kj}
\end{aligned}$$

Dengan kata lain,

$$\begin{aligned}
(A_n[[S, \omega]] + B_n[[S, \omega]])C_n[[S, \omega]] &= ([f_{ij}] + [g_{ij}])[h_{ij}] \\
&= [\alpha_{ij}][h_{ij}] \quad ; \alpha_{ij} = f_{ij} + g_{ij} \\
&= [\gamma_{ij}] \quad ; \gamma_{ij} = \sum_{k=1}^n \alpha_{ik} h_{kj} \\
&= [\delta_{ij} + \mu_{ij}] \quad ; \delta_{ij} = \sum_{k=1}^n f_{ik} h_{kj} \text{ dan} \\
&\quad \mu_{ij} = \sum_{k=1}^n g_{ik} h_{kj} \\
&= [\delta_{ij}] [\mu_{ij}] \\
&= [f_{ij}][h_{ij}] + [g_{ij}][h_{ij}] \\
&= A_n[[S, \omega]]C_n[[S, \omega]] + B_n[[S, \omega]]C_n[[S, \omega]].
\end{aligned}$$

Dari 1) dan 2) terbukti bahwa, berlaku hukum distributif kiri dan kanan pada operasi penjumlahan dan perkalian matriks pada $M_n(R[[S, \omega]])$. Karena (i)-(v), a), b), 1) dan 2) terpenuhi, maka terbukti bahwa $M_n(R[[S, \omega]])$ merupakan ring terhadap operasi penjumlahan dan perkalian matriks. □

Jika diberikan ideal I di ring R , maka himpunan

$$I[[S, \omega]] = \{f_{ij} \in R[[S, \omega]] | f_{ij}(s) \in I, \text{ untuk setiap } s \in S\}$$

merupakan ideal RDPTM $R[[S, \omega]]$ [32]. Dengan menerapkan cara yang serupa pada pendefinisian ideal RDPTM, berikut didefinisikan ideal dari $M_n(R[[S, \omega]])$.

Proposisi 3.2 Jika $I[[S, \omega]]$ ideal RDPTM $R[[S, \omega]]$, maka himpunan

$$J_n(R[[S, \omega]]) = \{A_n[[S, \omega]] = [f_{ij}] \in M_n(R[[S, \omega]]) | f_{ij} \in I[[S, \omega]]\}$$

merupakan ideal di $M_n(R[[S, \omega]])$.

Bukti.

i) Untuk sebarang $A_n[[S, \omega]], B_n[[S, \omega]] \in J_n(R[[S, \omega]])$, akan ditunjukkan $A_n[[S, \omega]] - B_n[[S, \omega]] = [f_{ij}] - [g_{ij}] \in J_n(R[[S, \omega]])$.

Ambil sebarang $A_n[[S, \omega]], B_n[[S, \omega]] \in J_n(R[[S, \omega]])$ dengan $A_n[[S, \omega]] = [f_{ij}]$ dan $B_n[[S, \omega]] = [g_{ij}]$. Jelas bahwa $f_{ij}, g_{ij} \in I[[S, \omega]]$. Karena $I[[S, \omega]]$ ideal $R[[S, \omega]]$, maka berakibat $f_{ij} - g_{ij} \in I[[S, \omega]]$.

Sehingga $[f_{ij} - g_{ij}] \in J_n(R[[S, \omega]])$. Sedangkan $[f_{ij} - g_{ij}] = [f_{ij}] - [g_{ij}] = A_n[[S, \omega]] - B_n[[S, \omega]]$. Dengan kata lain, terbukti $A_n[[S, \omega]] - B_n[[S, \omega]] \in J_n(R[[S, \omega]])$.

- ii) Untuk sebarang $P_n[[S, \omega]] \in M_n(R[[S, \omega]])$ dan $A_n[[S, \omega]] \in J_n(R[[S, \omega]])$, akan ditunjukkan $A_n[[S, \omega]]P_n[[S, \omega]], P_n[[S, \omega]]A_n[[S, \omega]] \in J_n(R[[S, \omega]])$.

Untuk sebarang $P_n[[S, \omega]] \in M_n(R[[S, \omega]])$ dengan $P_n[[S, \omega]] = [\alpha_{ij}]$ dan $A_n[[S, \omega]] \in J_n(R[[S, \omega]])$ dengan $A_n[[S, \omega]] = [f_{ij}]$ berlaku

$$A_n[[S, \omega]]P_n[[S, \omega]] = [f_{ij}][\alpha_{ij}] = [\mu_{ij}] \quad ; \mu_{ij} = \sum_{k=1}^n f_{ik}\alpha_{kj},$$

dengan $(f_{ik}\alpha_{kj})(s) = \sum_{t+u=s} f_{ik}(t)\omega_t(\alpha_{kj}(u))$ untuk setiap $s \in S$, dan

$$P_n[[S, \omega]]A_n[[S, \omega]] = [\alpha_{ij}][f_{ij}] = [\delta_{ij}] \quad ; \delta_{ij} = \sum_{m=1}^n \alpha_{im}f_{mj},$$

dengan $(\alpha_{im}f_{mj})(s) = \sum_{x+y=s} \alpha_{im}(x)\omega_x(f_{mj}(y))$ untuk setiap $s \in S$.

Dengan kata lain, untuk menunjukkan $A_n[[S, \omega]]P_n[[S, \omega]], P_n[[S, \omega]]A_n[[S, \omega]] \in J_n(R[[S, \omega]])$, cukup ditunjukkan $\mu_{ij}, \delta_{ij} \in I[[S, \omega]]$. Karena $I[[S, \omega]]$ ideal RDPTM $R[[S, \omega]]$, untuk sebarang $f_{ik}, f_{mj} \in I[[S, \omega]]$ dan $\alpha_{kj}, \alpha_{im} \in R[[S, \omega]]$, berlaku $f_{ik}\alpha_{kj}, \alpha_{im}f_{mj} \in I[[S, \omega]]$. Oleh karena itu, $\sum_{k=1}^n f_{ik}\alpha_{kj} = \mu_{ij}, \sum_{m=1}^n \alpha_{im}f_{mj} = \delta_{ij} \in I[[S, \omega]]$.

Dengan kata lain,

$$[\mu_{ij}] = [f_{ij}][\alpha_{ij}] = A_n[[S, \omega]]P_n[[S, \omega]] \in J_n(R[[S, \omega]])$$

dan

$$[\delta_{ij}] = [\alpha_{ij}][f_{ij}] = P_n[[S, \omega]]A_n[[S, \omega]] \in J_n(R[[S, \omega]])$$

Jadi terbukti bahwa $J_n(R[[S, \omega]])$ merupakan ideal $M_n(R[[S, \omega]])$.

Telah diketahui bahwa jika I_1, I_2, \dots, I_m ideal-ideal ring R , maka $\bigcap_{k=1}^m I_k$ juga ideal ring R . Hal ini juga berlaku pada ideal RDPTM, yang dijelaskan pada sifat berikut.

Lemma 3.3 Jika $I_1[[S, \omega]], I_2[[S, \omega]], \dots, I_m[[S, \omega]]$ ideal RDPTM $R[[S, \omega]]$ dengan I_1, I_2, \dots, I_m ideal-ideal ring R , maka $\bigcap_{k=1}^m (I_k[[S, \omega]])$ merupakan ideal RDPTM $R[[S, \omega]]$, serta berlaku

$$\bigcap_{k=1}^m (I_k[[S, \omega]]) = (\bigcap_{k=1}^m I_k)[[S, \omega]].$$

Bukti. Berdasarkan definisi ideal RDPTM, $I_k[[S, \omega]]$ adalah himpunan yang didefinisikan oleh

$$I_k[[S, \omega]] = \{f_{ij} \in R[[S, \omega]] \mid f_{ij}(s) \in I_k, \text{ untuk setiap } s \in S\},$$

dengan I_k adalah ideal ring R untuk $k = 1, 2, \dots, m$. Sedangkan, $(\bigcap_{k=1}^m I_k)[[S, \omega]]$ dapat didefinisikan sebagai himpunan

$$(\bigcap_{k=1}^m I_k)[[S, \omega]] = \{f_{ij} \in R[[S, \omega]] \mid f_{ij}(s) \in \bigcap_{k=1}^m I_k, \text{ untuk setiap } s \in S\}.$$

Untuk sebarang $f_{ij} \in \bigcap_{k=1}^m (I_k[[S, \omega]])$, akan ditunjukkan $f_{ij} \in (\bigcap_{k=1}^m I_k)[[S, \omega]]$. Dengan kata lain, akan ditunjukkan $\bigcap_{k=1}^m (I_k[[S, \omega]]) \subseteq (\bigcap_{k=1}^m I_k)[[S, \omega]]$.

$f_{ij} \in \bigcap_{k=1}^m (I_k[[S, \omega]])$ artinya $f_{ij} \in I_1[[S, \omega]]$, $f_{ij} \in I_2[[S, \omega]]$, ..., dan $f_{ij} \in I_m[[S, \omega]]$. Oleh karena itu, untuk setiap $s \in S$ berlaku $f_{ij}(s) \in I_1$, $f_{ij}(s) \in I_2$, ..., dan $f_{ij}(s) \in I_m$. Dengan kata lain, $f_{ij}(s) \in \bigcap_{k=1}^m I_k$ untuk setiap $s \in S$. Akibatnya, $f_{ij} \in (\bigcap_{k=1}^m I_k)[[S, \omega]]$. Jadi terbukti $\bigcap_{k=1}^m (I_k[[S, \omega]]) \subseteq (\bigcap_{k=1}^m I_k)[[S, \omega]]$.

Selanjutnya, untuk sebarang $f_{ij} \in (\bigcap_{k=1}^m I_k)[[S, \omega]]$, akan ditunjukkan $f_{ij} \in \bigcap_{k=1}^m (I_k[[S, \omega]])$.

Dengan kata lain, akan ditunjukkan $(\bigcap_{k=1}^m I_k)[[S, \omega]] \subseteq \bigcap_{k=1}^m (I_k[[S, \omega]])$.

$f_{ij} \in (\bigcap_{k=1}^m I_k)[[S, \omega]]$ artinya $f_{ij}(s) \in \bigcap_{k=1}^m I_k$ untuk setiap $s \in S$. Oleh karena itu, $f_{ij}(s) \in I_1$, $f_{ij}(s) \in I_2$, ..., dan $f_{ij}(s) \in I_m$. Akibatnya, $f_{ij} \in I_1[[S, \omega]]$, $f_{ij} \in I_2[[S, \omega]]$, ..., dan $f_{ij} \in I_m[[S, \omega]]$. Dengan kata lain, $f_{ij} \in \bigcap_{k=1}^m (I_k[[S, \omega]])$, yang artinya $(\bigcap_{k=1}^m I_k)[[S, \omega]] \subseteq \bigcap_{k=1}^m (I_k[[S, \omega]])$.

Jadi, terbukti bahwa $\bigcap_{k=1}^m (I_k[[S, \omega]]) = (\bigcap_{k=1}^m I_k)[[S, \omega]]$. □

Untuk selanjutnya, jika $I_k[[S, \omega]]$ ideal RDPTM $R[[S, \omega]]$, dengan I_k ideal R , untuk $k=1, 2, \dots, m$, maka ideal ring matriks $M_n(R[[S, \omega]])$ yang entri matriksnya merupakan anggota dari $I_k[[S, \omega]]$ dinotasikan oleh

$$J_n^k(R[[S, \omega]]) = \{A_n[[S, \omega]] = [f_{ij}] \in M_n(R[[S, \omega]]) | f_{ij} \in I_k[[S, \omega]]\}.$$

Sedangkan, himpunan semua matriks atas RDPTM yang entrinya merupakan anggota RDPTM atas irisan ideal ring R dinotasikan oleh

$$D_n(R[[S, \omega]]) = \{A_n[[S, \omega]] = [f_{ij}] \in M_n(R[[S, \omega]]) | f_{ij} \in (\bigcap_{k=1}^m I_k)[[S, \omega]]\}.$$

Kesamaan dua himpunan ini, diberikan oleh sifat berikut.

Proposisi 3.4 Jika $J_n^1(R[[S, \omega]]), J_n^2(R[[S, \omega]]), \dots, J_n^m(R[[S, \omega]])$ ideal $M_n(R[[S, \omega]])$, dengan $I_k[[S, \omega]]$ ideal RDPTM $R[[S, \omega]]$ dan I_k ideal ring R , untuk $k = 1, 2, \dots, m$, maka

$$\bigcap_{k=1}^m \{J_n^k(R[[S, \omega]])\} = D_n(R[[S, \omega]]).$$

Bukti. Untuk sebarang $A_n[[S, \omega]] = [f_{ij}] \in \bigcap_{k=1}^m \{J_n^k(R[[S, \omega]])\}$, akan ditunjukkan $A_n[[S, \omega]] = [f_{ij}] \in D_n(R[[S, \omega]])$. Dengan kata lain, akan ditunjukkan $\bigcap_{k=1}^m \{J_n^k(R[[S, \omega]])\} \subseteq D_n(R[[S, \omega]])$.

$A_n[[S, \omega]] = [f_{ij}] \in \bigcap_{k=1}^m \{J_n^k(R[[S, \omega]])\}$ artinya $[f_{ij}] \in J_n^1(R[[S, \omega]])$, $[f_{ij}] \in J_n^2(R[[S, \omega]])$, ..., $[f_{ij}] \in J_n^m(R[[S, \omega]])$. Oleh karena itu, $f_{ij} \in I_1[[S, \omega]]$, $f_{ij} \in I_2[[S, \omega]]$, ..., $f_{ij} \in I_m[[S, \omega]]$. Dengan kata lain, $f_{ij} \in \bigcap_{k=1}^m (I_k[[S, \omega]])$. Berdasarkan Lemma 3.3, $\bigcap_{k=1}^m (I_k[[S, \omega]]) = (\bigcap_{k=1}^m I_k)[[S, \omega]]$, sehingga diperoleh $f_{ij} \in (\bigcap_{k=1}^m I_k)[[S, \omega]]$. Dengan kata lain, $[f_{ij}] = A_n[[S, \omega]] \in D_n(R[[S, \omega]])$. Jadi terbukti $\bigcap_{k=1}^m \{J_n^k(R[[S, \omega]])\} \subseteq D_n(R[[S, \omega]])$.

Selanjutnya, untuk sebarang $A_n[[S, \omega]] = [f_{ij}] \in D_n(R[[S, \omega]])$, akan ditunjukkan $A_n[[S, \omega]] = [f_{ij}] \in \bigcap_{k=1}^m \{J_n^k(R[[S, \omega]])\}$. Dengan kata lain, akan ditunjukkan $D_n(R[[S, \omega]]) \subseteq \bigcap_{k=1}^m \{J_n^k(R[[S, \omega]])\}$.

$A_n[[S, \omega]] = [f_{ij}] \in D_n(R[[S, \omega]])$ artinya $f_{ij} \in (\bigcap_{k=1}^m I_k)[[S, \omega]]$. Berdasarkan Lemma 3.3, $\bigcap_{k=1}^m (I_k[[S, \omega]]) = (\bigcap_{k=1}^m I_k)[[S, \omega]]$, sehingga diperoleh $f_{ij} \in \bigcap_{k=1}^m (I_k[[S, \omega]])$. Oleh karena itu, diperoleh $f_{ij} \in I_1[[S, \omega]]$, $f_{ij} \in I_2[[S, \omega]]$, ..., $f_{ij} \in I_m[[S, \omega]]$. Dengan kata lain, $[f_{ij}] \in J_n^1(R[[S, \omega]])$, $[f_{ij}] \in J_n^2(R[[S, \omega]])$, ..., $[f_{ij}] \in J_n^m(R[[S, \omega]])$. Akibatnya, $[f_{ij}] = A_n[[S, \omega]] \in \bigcap_{k=1}^m \{J_n^k(R[[S, \omega]])\}$. Jadi terbukti $D_n(R[[S, \omega]]) \subseteq \bigcap_{k=1}^m \{J_n^k(R[[S, \omega]])\}$.

4. KESIMPULAN

Matriks atas RDPTM pada makalah ini, merupakan matriks berukuran $n \times n$ yang entri-entrinya merupakan elemen RDPTM $R[[S, \omega]]$ dan dinotasikan dengan $A_n[[S, \omega]]$. Dapat dikonstruksi himpunan matriks atas RDPTM $R[[S, \omega]]$, yang selanjutnya dinotasikan dengan $M_n(R[[S, \omega]])$. Terhadap operasi penjumlahan dan perkalian matriks, telah dibuktikan bahwa $M_n(R[[S, \omega]])$ merupakan ring. Selain itu, konstruksi ideal dari $M_n(R[[S, \omega]])$ juga berhasil dilakukan, yang selanjutnya dinotasikan dengan $J_n(R[[S, \omega]])$. Lebih lanjut, telah dibuktikan bahwa irisan semua ideal $M_n(R[[S, \omega]])$ sama dengan himpunan semua matriks atas RDPTM $R[[S, \omega]]$ yang entrinya merupakan anggota RDPTM atas irisan ideal-ideal ring R .

Untuk penelitian lebih lanjut, masih terbuka peluang untuk mengkaji sifat-sifat yang ada pada himpunan semua matriks atas RDPTM, seperti elemen idempotent dan nilpoten dari $M_n(R[[S, \omega]])$.

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PERANCANGAN SISTEM ESTIMASI INTENSITAS GEMPABUMI UNTUK PERINGATAN DINI

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Abstract

Indonesia is located at the junction of three tectonic plates and has many active faults. The consequence of this tectonic arrangement makes Indonesia prone to earthquakes. Therefore, earthquake mitigation efforts based on an early warning system need to be done. The design of an earthquake strength estimation system, based on python, for this early warning, analyzes the initial phase of the first three seconds since the arrival of the P wave, using parameters in the form of P_d (the maximum amplitude of the first three seconds of the arrival of the P wave). The resulting tools and systems consist of hardware in the form of Raspberry Pi3B + and ADXL345. The system will detect in real time and automatically trigger an earthquake using the STA / LTA method. When the P_d and T_d parameters have been obtained, the system will calculate and issue earthquake strength information, in the form of magnitude and intensity scale of earthquake damage MMI (Modified Mercally Intensity), which will then be sent automatically via the telegram application. Testing of tools and systems was carried out in an earthquake simulator, using the Padang earthquake parameters on 30 September 2009, 17:16:09 WIB. The results of the test produce an intensity scale of VIII MMI, these results are close to the results of the BMKG for the earthquake, with an intensity scale of VIII MMI. From these results the designed tools and systems can be used to provide early warning in the event of an earthquake.

Keywords: three seconds, earthquake, early warning.

Abstrak

Indonesia terletak pada pertemuan tiga lempeng tektonik dan memiliki banyak sesar aktif. Konsekuensi dari tatanan tektonik ini membuat Indonesia rawan gempa bumi. Oleh karena itu upaya mitigasi bencana gempa bumi berbasis sistem peringatan dini perlu dilakukan. Perancangan sistem estimasi kekuatan gempa bumi berbasis python untuk peringatan dini ini menganalisis fase awal tiga detik pertama sejak kedatangan gelombang P, dengan menggunakan parameter berupa P_d (amplitudo maksimum tiga detik pertama dari kedatangan gelombang P). Alat dan sistem yang dihasilkan terdiri

dari perangkat keras berupa Raspberry Pi3B+ dan ADXL345. Sistem akan mendeteksi secara *real time* dan otomatis adanya *trigger* gempa bumi dengan metode STA/LTA. Ketika parameter P_d diperoleh, sistem akan mengkalkulasi dan mengeluarkan informasi kekuatan gempa bumi berupa skala intensitas kerusakan gempa bumi MMI (*Modified Mercally Intensity*). Pengujian alat dan sistem dilakukan di simulator gempa bumi, dengan menggunakan parameter gempa bumi Padang 30 September 2009, pukul 17:16:09 WIB. Hasil dari pengujian menghasilkan skala intensitas VIII MMI, hasil tersebut mendekati hasil dari BMKG untuk gempa tersebut dengan skala intensitas VIII MMI. Dari hasil tersebut alat dan sistem yang dirancang dapat dimanfaatkan untuk memberikan peringatan dini jika terjadi gempa bumi.

Kata kunci: tiga detik, gempa bumi, peringatan dini.

PENDAHULUAN

Indonesia merupakan daerah rawan gempa bumi, bahkan rawan terhadap bencana tsunami. Kerusakan yang diakibatkan oleh gempa bumi tiap tahun akan terus bertambah seiring dengan penambahan populasi manusia. Oleh karena itu diperlukan suatu sistem peringatan dini. Indonesia telah memiliki sistem peringatan dini tsunami yang dikenal sebagai *Indonesia Tsunami Early Warning System (InaTews)*. InaTews adalah sistem peringatan dini yang bertujuan untuk memberikan informasi ancaman tsunami yang akan melanda daerah Indonesia dengan waktu peringatan diberikan lima menit setelah kejadian gempa bumi [1]

Namun saat ini di Indonesia belum dibangun sistem yang memberikan peringatan dini gempa bumi yang sedang terjadi sebagai dasar untuk melakukan antisipasi dini sebelum efek dari kerusakan gempa bumi itu dirasakan disuatu wilayah, yang sering disebut Sistem Peringatan Dini Gempa bumi (SPDG). Oleh karena itu dibutuhkan kajian yang bisa memberikan sinyal dini akan terjadinya bencana gempa bumi sehingga pemerintah dan masyarakat bisa mengambil langkah-langkah untuk menghadapi bencana tersebut sebelum terjadi, hal ini bisa menekan dan meminimalisir jatuhnya korban serta kerusakan infrastruktur. SPDG akan mendiseminasikan informasi estimasi skala kerusakan Intensitas gempa bumi sebelum kedatangan getaran gempa bumi yang merusak. Getaran gempa bumi yang merusak tersebut adalah gelombang S dan gelombang permukaan. Rangkaian gelombang gempa bumi akan datang berturut-turut dari yang tercepat hingga yang terlambat yaitu gelombang P, gelombang S dan gelombang permukaan[2][3][4].

Penelitian ini dimaksud untuk merancang SPDG berbasis bahasa pemrograman *Python* menggunakan fase tiga detik pertama gelombang P pada gempa yang terjadi. Kemudian sistem akan menganalisa secara otomatis untuk menghasilkan nilai PGA (*Peak Ground Acceleration*) kemudian mengkonversinya menjadi skala Intensitas MMI.

Tujuan penelitian ini adalah merancang dan menganalisis SPDG yang dapat memberikan secara cepat informasi estimasi skala Intensitas kerusakan gempa bumi MMI. Informasi kekuatan gempa bumi tersebut diperoleh dari hubungan parameter tiga detik awal kedatangan gelombang P berupa P_d (amplitudo maximum tiga detik pertama

dari kedatangan gelombang P). Perhitungan estimasi kekuatan gempabumi secara cepat tersebut diharapkan dapat dimanfaatkan masyarakat agar lebih cepat melakukan mitigasi jika terjadi gempabumi.

METODE PENELITIAN

Alur metode dalam penelitian ini digambarkan pada **Gambar 1**. Dalam penelitian ini digunakan data sinyal percepatan, komponen vertikal dari sensor percepatan ADXL345, data itu secara otomatis masuk ke sistem pengolahan berbasis *python*. Selanjutnya sinyal difilter untuk menghilangkan *noise* atau gangguan akibat pengaruh selain dari sinyal asli gempabumi yang sedang terjadi.

Jika ada trigger gempabumi pada sinyal maka sistem akan otomatis mem-pick gelombang P dengan metode STA/LTA. Pada proses deteksi gelombang P ini apabila proses perhitungan rasio (ϵ), STA dengan LTA lebih besar dari nilai ambang yang diberikan pengguna ($\epsilon >$ nilai ambang), maka akan ditampilkan hasil deteksi otomatis gelombang P berupa waktu tiba gelombang P. Dalam penelitian ini diberikan nilai ambang 1,5 untuk mengindikasikan adanya *trigger* gempabumi, rumus STA/LTA dapat ditulis dengan **Persamaan 1, 2 dan 3** berikut :

$$\epsilon = \frac{STA_j}{LTA_j} \quad (1)$$

dimana

$$STA(t) = \sum_{j=0}^{s-1} |w(t-j)| \cdot \frac{1}{s} \quad (2)$$

$$LTA(t) = \sum_{j=0}^{s-1} |w(t-j)| \cdot \frac{1}{L} \quad (3)$$

dengan ϵ adalah rasio STA dengan LTA, s panjang waktu STA dalam detik dan L panjang waktu LTA dalam detik.

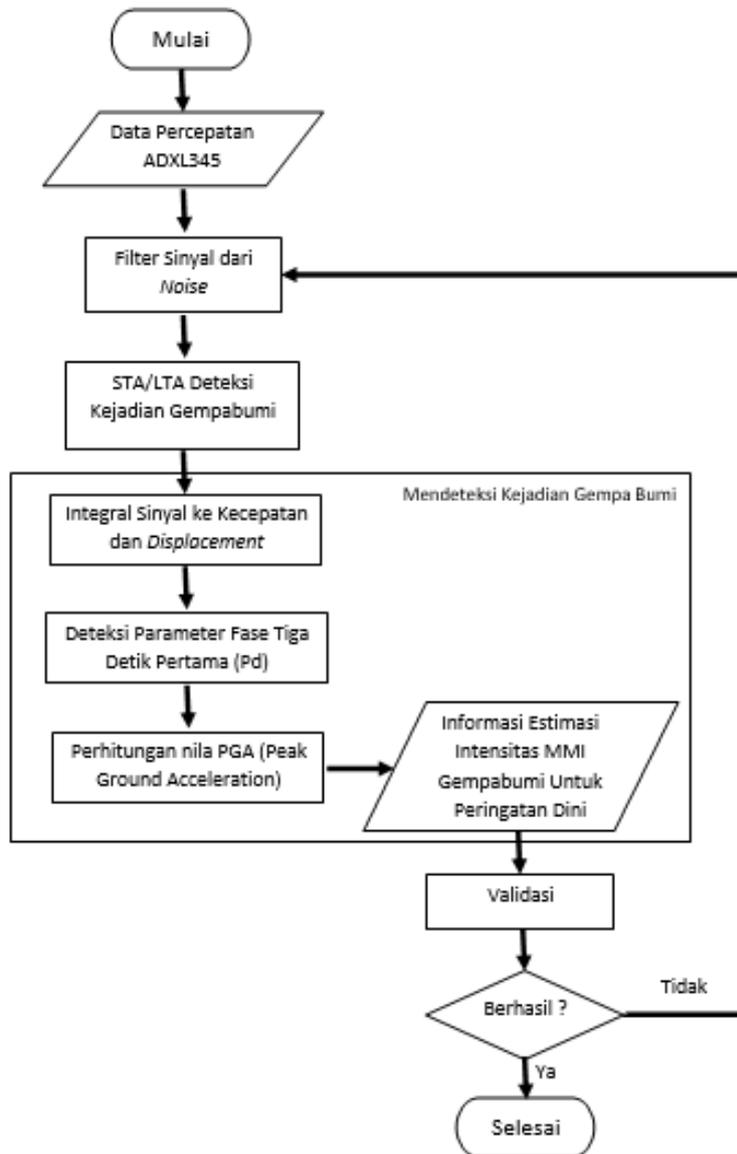
Tahap berikutnya sinyal akan diintegrasikan dari percepatan ke kecepatan dan *displacement*. Setelah diperoleh sinyal *displacement* kemudian dilakukan deteksi otomatis oleh sistem untuk memperoleh nilai parameter fase tiga detik pertama yaitu nilai amplitudo max pada fase awal 3 detik pertama (P_d).

Nilai P_d kemudian dimasukkan ke persamaan peringatan dini gempabumi untuk memperoleh estimasi nilai PGA yang kemudian dikonversi ke skala intensitas kerusakan gempabumi MMI. Dalam penelitian ini digunakan **Persamaan 4** yang merupakan persamaan Peringatan Dini Gempabumi (PDG) untuk wilayah Jawa Barat [2], [3].

$$\log(PGA) = 1.117 \log(P_d) + 0.441 \quad (4)$$

dengan PGA nilai percepatan maksimum akibat gempa (cm/s^2) dan P_d merupakan amplitudo maksimum dari tiga detik pertama gelombang P.

Penelitian ini divalidasi dengan menggunakan simulator gempabumi di BMKG.

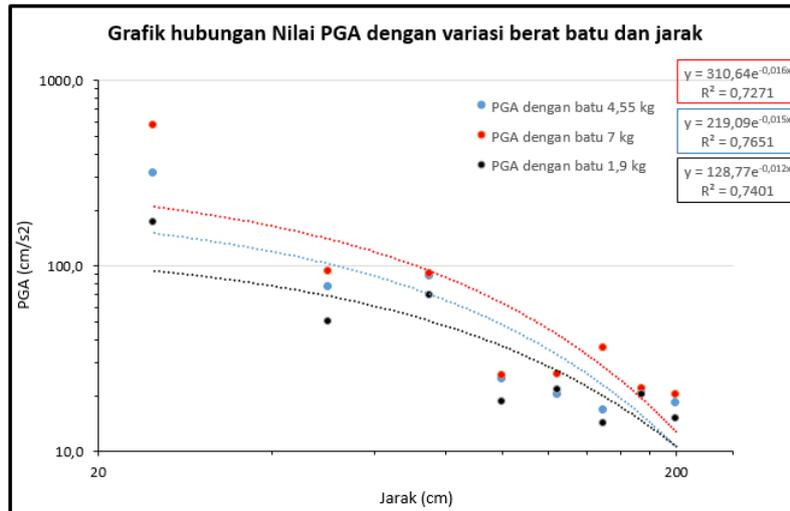


Gambar 1. Alur metode penelitian.

Rancangan SPDG akan diletakkan di dalam simulator gempa kemudian dilakukan pengujian terhadap sistem dan hasil yang diperoleh akan didokumentasikan. Setelah diperoleh estimasi intensitas MMI gempa dari hasil rancangan SPDG, kemudian dibandingkan dengan parameter gempabumi dari simulator gempa. Informasi intensitas MMI gempabumi dari rancangan SPDG diharapkan mendekati intensitas MMI dari simulator gempa. **Gambar 1** menunjukkan diagram alir metode penelitian yang dilakukan.

HASIL DAN PEMBAHASAN

Dalam pengujian laboratorium sistem diuji dengan menjatuhkan beban berupa batu dengan berat bervariasi dari jarak yang berbeda untuk melihat respon dari sistem.



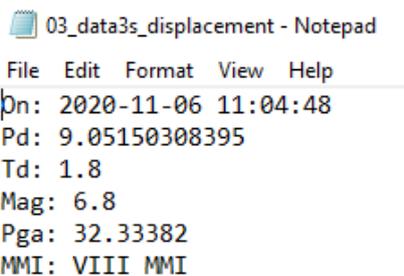
Gambar 2. Grafik PGA dengan variasi berat dan jarak.

Gambar 2 merupakan grafik hubungan PGA dengan jarak menjatuhkan beban batu, untuk berat uji batu yang berbeda, grafik tersebut ditampilkan dalam skala logaritmik. Dari grafik tersebut menunjukkan bahwa jarak dengan nilai PGA memiliki hubungan perbandingan terbalik, semakin jauh jarak pengujian menjatuhkan beban semakin kecil nilai PGA yang dihasilkan oleh alat. Begitupun dengan variasi berat beban yang mewakili variasi magnitude dimana semakin berat beban semakin besar nilai PGA[5].

Kemudian dilakukan pengujian dengan simulator gempabumi untuk melihat performa keseluruhan sistem. Pengujian kali ini dengan menggunakan parameter gempabumi Padang tanggal 30 September 2009. Pada **Tabel 1** ditunjukkan parameter dari gempabumi Padang 2009.

Tabel 1. Parameter gempabumi Padang.

Parameter Gempabumi Padang 30 September 2009	
Tanggal	30-09-2009
OT	17:16:09 WIB
Lokasi	0.84 LS - 99.65 BT
Kedalaman	71 Km
Magnitudo	7.9
Intensitas (MMI)	VIII MMI di Padang



Gambar 3. Hasil analisa sistem.

Setelah sistem mendeteksi terjadinya gempabumi, maka sistem akan mengkalkulasi kekuatan gempabumi tersebut. Hasil analisa sistem terhadap simulasi gempabumi Padang ditunjukkan pada **Gambar 3**.

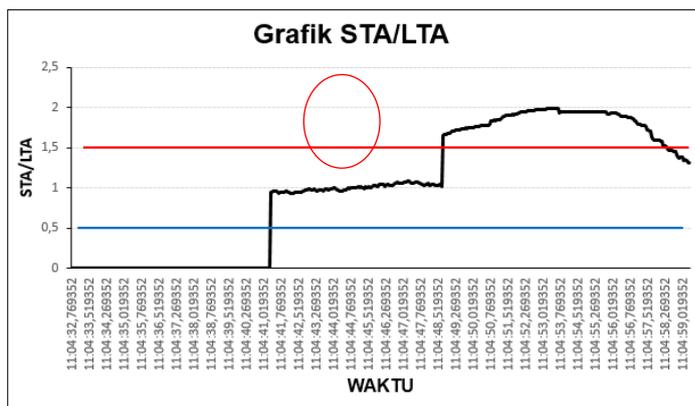
Ada beberapa parameter yang terbentuk didalam parameter tersebut yaitu:

1. On: 2020-11-06 11:04:48

Merupakan hasil analisis sitem dengan STA/LTA yang mengindikasikan terjadinya *trigger*. Dapat dilihat pada **Gambar 4** hasil grafik STA/LTA dan posisi dimana *trigger* mulai naik melebihi ambang batas 1,5.

2. P_d : 9.05150308935 cm

Nilai ini menunjukkan amplitudo maximum dari tiga detik pertama gelombang P, pada komponen *displacement* yang dicatat sistem bernilai 9.05150308935 cm. Setelah diperoleh nilai ini dilakukan kalkulasi untuk memperoleh nilai estimasi PGA (*Peak Ground Acceleration*) secara cepat dalam waktu tiga detik setelah terjadinya gempabumi. Proses kalkulasinya dengan memasukkan nilai tersebut kedalam **Persamaan 1**.



Gambar 4. Grafik STA/LTA.

3. P_{ga} : 32.33382 cm/s²

Hasil kalkulasi sistem terhadap simulasi gempabumi Padang tersebut menghasilkan estimasi PGA (*Peak Ground Acceleration*) bernilai 32.33382 cm/s².

4. MMI: VIII MMI

Setelah nilai PGA diperoleh kemudian dikonversi ke dalam skala MMI. Nilai tersebut merupakan nilai estimasi intensitas MMI atau kerusakan akibat simulasi gempabumi Padang tersebut dimana hasil analisa sistem menunjukkan nilai dengan skala VIII MMI.

Langkah pengujian berikutnya dengan membandingkan estimasi kekuatan simulasi gempabumi Padang hasil analisa sistem penelitian ini dengan nilai kekuatan sebenarnya dari gempabumi Padang tersebut. Perbandingan tersebut ditunjukkan pada **Tabel 3**.

Tabel 3. Perbandingan SPDG dan BMKG

	Sistem	BMKG
Intensitas (MMI)	VIII	VIII

Sistem yang dibuat dalam penelitian ini jika dilihat pada **Tabel 3**, nilai estimasi intensitas MMI gempabumi yang dikeluarkan mendekati nilai sebenarnya. Dengan proses perhitungan yang cepat dalam waktu tiga detik dari kejadian gempa dan hasil estimasi kekuatan gempabumi yang mendekati kekuatan gempabumi sebenarnya, maka sistem ini baik dimanfaatkan dalam usaha memberikan estimasi kekuatan gempabumi secara cepat sebagai upaya mitigasi dalam menghadapi bahaya gempabumi.

KESIMPULAN

Perancangan sistem estimasi intensitas gempabumi secara cepat untuk peringatan dini berbasis python dapat bekerja dengan cukup baik dalam mengestimasi kekuatan gempabumi. Dengan memanfaatkan waktu dari 3 (tiga) detik pertama sejak kedatangan gelombang P gempabumi, sistem dapat memberikan estimasi intensitas gempabumi yang dapat dimanfaatkan sebagai informasi peringatan dini dalam upaya mitigasi terhadap bahaya gempabumi.

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THE $X[[S]]$ -SUB-EXACT SEQUENCE OF GENERALIZED POWER SERIES RINGS

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Abstract

Let R be a ring, $(S, +, \leq)$ a strictly ordered monoid, and K, L, M are R -modules. Then, we can construct the Generalized Power Series Modules (GPSM) $K[[S]]$, $L[[S]]$, and $M[[S]]$, which are the module over the Generalized Power Series Rings (GPSR) $R[[S]]$. In this paper, we investigate the property of $X[[S]]$ -sub-exact sequence on GPSM $L[[S]]$ over GPSR $R[[S]]$.

Key Words: strictly ordered monoid, generalized power series rings, generalized power series module, exact sequence, X -sub-exact sequence.

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Introduction

A non-empty set of S with an associative binary "*" is called a semigroup. If S has an identity element, then $(S, *)$ is called a monoid. Furthermore, if each element of S has an inverse, then $(S, *)$ is called a group (Howie 1995). A ring $(R, +, \cdot)$ is a non-empty set of R with two binary operations. $(R, +)$ is a commutative group, (R, \cdot) a semigroup, and satisfies the left and right distributive laws (Adkins and Weintraub 1992).

One example of a ring is the polynomial ring $R[X]$, which is defined as the set of all functions from non-negative integers $\mathbb{N} \cup \{0\}$ to ring R with finite support. Furthermore, this ring is generalized into the power series ring $R[[X]]$ by removing the finite support conditions (Hungerford 1974). Furthermore, the polynomial ring $R[X]$ can be generalized by changing its function domain to any S semigroup. This ring is then known as the semigroup ring and is denoted by $R[S]$ (Gilmer 1984).

A partially ordered relation is a binary relation " \leq " on a non-empty set of S that fulfills reflexive, anti-symmetric, and transitive properties. Furthermore, (S, \leq) is called a partially ordered set. An order " \leq " is said to be trivial if for any $s, t \in S, s \leq t$ results in $s = t$ and is said to be strictly ordered if $(\forall x, y, s \in S)(x < y \rightarrow x + s < y + s)$. Furthermore, (S, \leq) is said to be Artinian if it does not contain any infinite strictly decreasing sequence $s_1 > s_2 > s_3 > \dots$, and is said to be narrow if it does not contain an infinite subset consisting of pairwise incomparable elements. (Elliott and Ribenboim 1990).

By using the Artinian and narrow partially ordered set concept, ring semigroup $R[S]$ can be generalized into a Generalized Power Series Ring (GPSR) by weakening the finite support condition that became Artinian and narrow. Furthermore, this ring is denoted by $R[[S, \leq]]$ or abbreviated as $R[[S]]$ (Ribenboim 1990). Furthermore, the research results relating to the properties that apply in GPSR can be seen in ((Ribenboim 1991), (Ribenboim 1992), (Priess-Crampe and Ribenboim 1993), (Benhissi and Ribenboim 1993), (Ribenboim 1994), (Ribenboim 1995).

Furthermore, the structure of GPSR $R[[S]]$ can be generalized by applying a monoid homomorphism $\omega: S \rightarrow \text{End}(R)$ to the convolution multiplication operation (Mazurek and Ziemkowski 2007). This ring is called the Skew Generalized Power Series Ring (SGPSR), and it is denoted by $R[[S, \omega]]$. The properties related to the structure of SGPSR $R[[S, \omega]]$ can be seen in ((Mazurek and Ziemkowski 2008); (Mazurek and Ziemkowski 2009); (Mazurek and Ziemkowski 2010), (Faisol 2009), (Faisol 2013), (Faisol 2014), (Faisol, Surodjo, and Wahyuni 2016), (Faisol, Surodjo, and Wahyuni 2018), (Faisol and Fitriani 2019).

It is known that a ring can be seen as a module over itself. Based on this, we can form the Generalized Power Series Module (GPSM) $M[[S]]$, which is a module over GPSR $R[[S]]$ where M is a module over the ring R (Varadarajan 2001a). In addition to the GPSM $M[[S]]$ structure, the necessary and sufficient conditions of $M[[S]]$ to be Noetherian module over $R[[S]]$ can be seen in (Varadarajan 2001b). Furthermore, the generalization of Noetherian property on GPSM $M[[S]]$ can be seen in (Faisol, Surodjo, and Wahyuni 2019a), which is about the necessary and sufficient conditions of GPSM $M[[S]]$ is a $T[[S]]$ -Noetherian module. This is obtained by generalizing the necessary and sufficient conditions for the polynomial module $M[[X]]$ to be $S[X]$ -Noetherian module over polynomial ring $R[X]$ (Faisol, Surodjo, and Wahyuni 2019c), and applies the relationship between almost generated module, almost Noetherian module and T -Noetherian module (Faisol, Surodjo, and Wahyuni 2019b).

The Noetherian properties of an R -module M can be investigated through an exact sequence. If there is an exact sequence $A \xrightarrow{f} B \xrightarrow{g} C$ where A and C are Noetherian, then B is a Noetherian R -module (Wisbauer 1991). The generalization of the exact sequence in the R -module is investigated by (Davvaz and Parnian-Garamaleky 1999). This result is obtained by replacing submodule 0 with submodule $U \subseteq C$, called the U -exact sequence. Another study related to the properties of the U -exact sequence can be seen in ((Davvaz and Shabani-Solt 2002) (Anvariye and Davvaz 2005)).

Motivated by the U-exact sequence definition, the X-sub-exact sequence concept was introduced in (Fitriani, Surodjo, and Wijayanti 2016), which is a generalization of the exact sequence. Besides that, the generalization of an R-module generator to become a U-generator has been reviewed in (Fitriani, Wijayanti, and Surodjo 2018b). Furthermore, by using the concept of sub-linearly independent modules (Fitriani, Surodjo, and Wijayanti 2017), a basis and free module relative to a family of modules over R can be defined (Fitriani, Wijayanti, and Surodjo 2018a).

It was explained earlier that Varadarajan determines the necessary and sufficient conditions of GPSM $M[[S]]$ is a Noetherian $R[[S]]$ -module; this will be easier to do using the exact sequence concept. Therefore, this motivates us to study the exact sequence of $R[[S]]$ -modules and construct $X[[S]]$ -sub-exact sequence on GPSM $M[[S]]$. Besides, this also provides an opportunity to investigate the properties that satisfy them.

the Research Methods

The research methods are based on the study of literature. They relate to the concept of partially ordered set, strictly ordered monoid, Artinian and narrow properties, generalized power series rings (GPSR), generalized power series modules (GPSM), exact-sequences, and X-sub-exact sequences.

The results of this study obtained by constructing the exact sequence and $X[[S]]$ -sub-exact sequence over an $R[[S]]$ -module, as well as investigating the properties that apply in it.

the Results of the Research and the Discussion

Before discussing the definition and properties of the $X[[S]]$ -sub-exact sequence, the following is explained about the structure of GPSM $M[[S]]$ over GPSR $R[[S]]$ as well as the exact and X-sub-exact sequence definition, which have been explained in ((Ribenoim 1990), (Varadarajan 2001a), (Wisbauer 1991), dan (Fitriani et al. 2016)).

We were given a strictly ordered monoid $(S, +, \leq)$ and commutative ring R with unit element 1. Next, is defined as the set $R[[S]] = \{f: S \rightarrow R \mid \text{supp}(f) \text{ Artin dan narrow}\}$, with $\text{supp}(f) = \{s \in S \mid f(s) \neq 0\}$. Against the operation of the addition function:

$$(f + g)(s) = f(s) + g(s)$$

and convolution multiplication operations:

$$(f \cdot g)(s) = \sum_{t+u=s} f(t)g(u),$$

for each $s \in S, t \in \text{supp}(f), u \in \text{supp}(g)$ and $f, g \in R[[S]]$, it can be shown $(R[[S]], +, \cdot)$ is a ring. Furthermore, this ring is called the Generalized Power Series Ring (GPSR).

Furthermore, if given an R-module M, then the set $M[[S]] = \{\alpha: S \rightarrow M \mid \text{supp}(\alpha) \text{ Artin dan narrow}\}$ can be formed. Against the operation of the addition function :

$$(\alpha + \beta)(s) = \alpha(s) + \beta(s)$$

and scalar multiplication operations:

$$(\alpha \cdot f)(s) = \sum_{t+u=s} \alpha(t)f(u),$$

for each $s \in S, t \in \text{supp}(\alpha), u \in \text{supp}(f), f \in R[[S]],$ and $\alpha, \beta \in M[[S]],$ it can be shown that $M[[S]]$ is an $R[[S]]$ -module. This module is called the Generalized Power Series Module (GPSM).

The following is the definition of the exact sequence and X-sub-exact sequence over an R-modules. Let R be a ring and M_i an R-module for each $i.$ R-module sequence

$$\dots \rightarrow M_{i-1} \xrightarrow{f_i} M_i \xrightarrow{f_{i+1}} M_{i+1} \rightarrow \dots$$

is said to be exact in M_i if there are R-homomorphism f_i and f_{i+1} that satisfies $\text{Im}(f_i) = \text{Ker}(f_{i+1}).$ The sequence is said to be exact if it is exact at every $M_i.$

Furthermore, this exact sequence is generalized to the X-sub-exact sequence. Suppose K, L, M are modules over R and X is a submodule of L. Triple (K, L, M) is said to be X-sub-exact over L if there are R-homomorphism f and g such that the sequence $K \xrightarrow{f} X \xrightarrow{g} M$ is the exact sequence over R-modules.

Next, all submodules X of L can be collected, so the triple (K, L, M) is X-sub-exact over L. Furthermore, this set is denoted by $\sigma(K, L, M).$ In other words, $\sigma(K, L, M) = \{X \leq L \mid (K, L, M) \text{ X-sub-exact over } L\}.$

Now, we define the exact sequence of GPSR.

Definition 1. Let R be a ring, (S, \leq) a strictly ordered monoid, and M_i modules over R for every $i.$ Given GPSR $R[[S]]$ and GPSM $M_i[[S]].$ An $R[[S]]$ -module sequence

$$\dots \rightarrow M_{i-1}[[S]] \xrightarrow{\mu_i} M_i[[S]] \xrightarrow{\mu_{i+1}} M_{i+1}[[S]] \rightarrow \dots$$

is said to be exact in $M_i[[S]]$ if there are $R[[S]]$ -homomorphisms μ_i and μ_{i+1} that satisfy $\text{Im}(\mu_i) = \text{Ker}(\mu_{i+1}).$ Furthermore, this sequence is said to be exact if it is exact at every $M_i[[S]].$

It is known that, if X is the submodule of M over R, then the set $X[[S]] = \{\alpha \in M[[S]] \mid \alpha(s) \in X; \forall s \in S\}$ is the submodule of $M[[S]]$ over $R[[S]].$ The following is the definition of X[[S]]-sub-exact sequence of GPSR.

Definition 2. Let R be a ring, (S, \leq) a strictly ordered monoid, and K, L, M are the modules over R. Given GPSR $R[[S]]$ and GPSM $K[[S]], L[[S]]$ and $M[[S]].$ If X is a submodule of L, the triple $(K[[S]], L[[S]], M[[S]])$ is said to be X[[S]]-sub-exact over $R[[S]]$ if there are $R[[S]]$ -homomorphisms μ and ρ so that the sequence $K[[S]] \xrightarrow{\mu} X[[S]] \xrightarrow{\rho} M[[S]]$ is the exact sequence over $R[[S]].$

Based on Definition 2, we can set all $R[[S]]$ -submodules $X[[S]]$ of $L[[S]]$ so that triple $(K[[S]], L[[S]], M[[S]])$ is X[[S]]-sub-exact over $R[[S]].$ This set is then denoted by $\sigma(K[[S]], L[[S]], M[[S]])$ or written as $\sigma(K[[S]], L[[S]], M[[S]]) = \{X[[S]] \leq L[[S]] \mid (K[[S]], L[[S]], M[[S]]) \text{ is X[[S]]-sub-exact over } R[[S]]\}.$

Next, the $X[[S]]$ -sub-exact characteristics of GPSR are given as the main results in this study.

Proposition 3. For $i = 1, 2$, let K_i, L_i, M_i are the modules over R , X_i a submodule of L_i , and (S, \leq) a strictly ordered monoid. If $X_1[[S]] \in \sigma(K_1[[S]], L_1[[S]], M_1[[S]])$ and $X_2[[S]] \in \sigma(K_2[[S]], L_2[[S]], M_2[[S]])$, then $X_1[[S]] \times X_2[[S]] \in \sigma(K_1[[S]] \times K_2[[S]], L_1[[S]] \times L_2[[S]], M_1[[S]] \times M_2[[S]])$.

Proof: Because it is known that $X_1[[S]] \in \sigma(K_1[[S]], L_1[[S]], M_1[[S]])$ and $X_2[[S]] \in \sigma(K_2[[S]], L_2[[S]], M_2[[S]])$, then clearly there is $R[[S]]$ -homomorphism μ_1, ρ_1, μ_2 , and ρ_2 so that $K_1[[S]] \xrightarrow{\mu_1} X_1[[S]] \xrightarrow{\rho_1} M_1[[S]]$ and $K_2[[S]] \xrightarrow{\mu_2} X_2[[S]] \xrightarrow{\rho_2} M_2[[S]]$ are exact sequences.

Next is defined function $\mu: K_1[[S]] \times K_2[[S]] \rightarrow X_1[[S]] \times X_2[[S]]$, where $\mu((\alpha_1, \alpha_2)) = (\mu_1(\alpha_1), \mu_2(\alpha_2))$, for each $(\alpha_1, \alpha_2) \in K_1[[S]] \times K_2[[S]]$ and $\rho: X_1[[S]] \times X_2[[S]] \rightarrow M_1[[S]] \times M_2[[S]]$, where $\rho((\beta_1, \beta_2)) = (\rho_1(\beta_1), \rho_2(\beta_2))$, for each $(\beta_1, \beta_2) \in X_1[[S]] \times X_2[[S]]$.

Based on the definitions of the functions μ and ρ , it can be shown easily that the functions μ and ρ are $R[[S]]$ -homomorphisms. Therefore, the sequence $K_1[[S]] \times K_2[[S]] \xrightarrow{\mu} X_1[[S]] \times X_2[[S]] \xrightarrow{\rho} M_1[[S]] \times M_2[[S]]$ is an exact sequence. In other words, $X_1[[S]] \times X_2[[S]] \in \sigma(K_1[[S]] \times K_2[[S]], L_1[[S]] \times L_2[[S]], M_1[[S]] \times M_2[[S]])$. \square

As a direct result of Proposition 3, the following properties are obtained for a set of indexes Δ .

Corollary 4. Let $K_\delta[[S]], L_\delta[[S]], M_\delta[[S]]$ are a family of $R[[S]]$ -module and $X_\delta[[S]]$ is a submodule of $L_\delta[[S]]$ for every $\delta \in \Delta$. If $X_\delta[[S]] \in \sigma(K_\delta[[S]], L_\delta[[S]], M_\delta[[S]])$ for every $\delta \in \Delta$, then $\prod_{\delta \in \Delta} X_\delta[[S]] \in \sigma(\prod_{\delta \in \Delta} K_\delta[[S]], \prod_{\delta \in \Delta} L_\delta[[S]], \prod_{\delta \in \Delta} M_\delta[[S]])$

The following properties show that if triple $(0, L[[S]], M[[S]])$ $X_1[[S]]$ -sub-exact and dan also $X_2[[S]]$ -sub-exact, then triple $(0, L[[S]], M[[S]])$ is $(X_1[[S]] \cap X_2[[S]])$ -sub-exact over $R[[S]]$.

Proposition 5. Suppose that L and M are modules over R and (S, \leq) a strictly ordered monoid. Given $R[[S]]$ -modules $L[[S]]$ and $M[[S]]$, and $X_1[[S]], X_2[[S]]$ are submodules of $L[[S]]$. If $X_1[[S]], X_2[[S]] \in \sigma(0, L[[S]], M[[S]])$, then $X_1[[S]] \cap X_2[[S]] \in \sigma(0, L[[S]], M[[S]])$.

Proof: Since $X_1[[S]], X_2[[S]] \in \sigma(0, L[[S]], M[[S]])$, then there are $R[[S]]$ -homomorphisms ρ_1 and ρ_2 such that $0 \rightarrow X_1[[S]] \xrightarrow{\rho_1} M[[S]]$ and $0 \rightarrow X_2[[S]] \xrightarrow{\rho_2} M[[S]]$ are exact sequences. Therefore, ρ_1 and ρ_2 are $R[[S]]$ -monomorphisms. Next, it is defined as $\rho = \rho_1|_{X_1[[S]] \cap X_2[[S]]}$. Then, ρ is an $R[[S]]$ -monomorphism. Therefore, $0 \rightarrow X_1[[S]] \cap X_2[[S]] \xrightarrow{\rho} M[[S]]$ is an exact sequence. So, it is proved that $X_1[[S]] \cap X_2[[S]] \in \sigma(0, L[[S]], M[[S]])$. \square

The properties described in Proposition 5 cause the following properties to take the consequence.

Corollary 6. Suppose L and M are modules over R , and (S, \leq) is strictly ordered monoid. Given GPSM $L[[S]]$ and $M[[S]]$ over GPSR $R[[S]]$, and $X_\delta[[S]]$ is a submodule of $M[[S]]$ for every $\delta \in \Delta$. If $X_\delta[[S]] \in \sigma(0, L[[S]], M[[S]])$ for each $\delta \in \Delta$, then $\bigcap_{\delta \in \Delta} X_\delta[[S]] \in \sigma(0, L[[S]], M[[S]])$

Example 7. After the properties related to $X[[S]]$ -sub-exact sequence of GPSR are given, here are examples:

1. Triple $(R[X], R[X], 0)$ is R -sub-exact on $R[X]$, where R -homomorphism $f: R[X] \rightarrow R$ is defined by

$$f(a_0 + a_1x + \dots + a_nx^n) = a_0$$

and g is zero mappings, such that $R[X] \xrightarrow{f} R \xrightarrow{g} 0$ is an exact sequence.

2. Triple $(R[X], R[X], R[X])$ is a 0-sub-exact on $R[X]$, because $R[X] \xrightarrow{g} 0 \xrightarrow{i} R[X]$ is an exact sequence, where the zero mapping g and inclusion i are R -homomorphisms.

3. If $I[[S]]$ is ideal of $R[[S]]$, then we can form the exact sequence

$$I[[S]] \xrightarrow{i} R[[S]] \xrightarrow{\pi} R[[S]]/I[[S]], \text{ where } i \text{ is an identity and } \pi \text{ a natural}$$

homomorphism.

Conclusion and Suggestion

If given GPSM $K[[S]]$, $L[[S]]$, $M[[S]]$ over GPSR $R[[S]]$, then we can form a set of all submodule $X[[S]]$ of $L[[S]]$ so that triple $(K[[S]], L[[S]], M[[S]])$ is $X[[S]]$ -sub-exact.

If $X_\delta[[S]] \in \sigma(K_\delta[[S]], L_\delta[[S]], M_\delta[[S]])$ for each $\delta \in \Delta$, then $\prod_{\delta \in \Delta} X_\delta[[S]] \in \sigma(\prod_{\delta \in \Delta} K_\delta[[S]], \prod_{\delta \in \Delta} L_\delta[[S]], \prod_{\delta \in \Delta} M_\delta[[S]])$. If $X_\delta[[S]] \in \sigma(0, L[[S]], M[[S]])$ for each $\delta \in \Delta$, then $\bigcap_{\delta \in \Delta} X_\delta[[S]] \in \sigma(0, L[[S]], M[[S]])$.

In this paper, there are still many opportunities to investigate the characterization of the $X[[S]]$ -sub-exact sequence of GPSR $R[[S]]$. Also, investigating the necessary and sufficient conditions for $X[[S]]$ to be a Noetherian module over $R[[S]]$, where $K[[S]]$, $M[[S]]$ are Noetherian modules, but $L[[S]]$ is not Noetherian.

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MULTIVARIATE ANALYSIS WITH M-ESTIMATION ON DATA CONTAINING OUTSIDE

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Abstract

Regression analysis is the most widely used statistical method in various fields, both economic and social. Least Square Method (LSM) is the most frequently used method to estimate regression model parameters. Outliers are cases or data that have unique characteristics that look very different from other observations and appear in the form of extreme values. To overcome this problem, one of the methods used is the robust method. The M-estimator is one of the robust regression estimators. The purpose of this study is to overcome outliers in the stock price data of PT. Medco Energi Internasional Tbk. with the exchange rate of the rupiah against the dollar using the M-estimate. The results show that the M-estimate is quite good in overcoming data containing outliers.

Key words : M-Estimation, MKT, Robust Regression.

Abstrak

Analisis regresi adalah metode statistika yang paling banyak digunakan di berbagai bidang baik ekonomi maupun sosial. Metode Kuadrat Terkecil (MKT) merupakan metode yang paling sering digunakan untuk mengestimasi parameter model regresi. Pencilan adalah kasus atau data yang memiliki karakteristik unik yang terlihat sangat berbeda jauh dari observasi-observasi lainnya dan muncul dalam bentuk nilai ekstrim. Untuk mengatasai masalah ini, salah satu metode yang digunakan adalah metode *robust*. Estimasi-M merupakan salah satu estimator regresi *robust*. Tujuan dari penelitian ini adalah mengatasi pencilan pada data harga saham PT. Medco Energi Internasional Tbk. dengan nilai tukar rupiah terhadap dollar menggunakan estimasi-M. Hasil penelitian menunjukkan bahwa estimasi-M cukup baik dalam mengatasi data yang mengaandung pencilan.

Kata kunci : Estimasi-M, MKT, Regresi Robust.

I. Introduction

Linear regression is a statistical method used to model the relationship between the dependent variable (dependent; response; Y) and one or more independent variables (independent; predictor; X). In general, linear regression consists of two, namely simple linear regression where there is one dependent variable and one independent variable X, while multiple linear regression where there is one dependent variable Y and several independent variables X.

In the case of the linear regression model, it is possible that there are outliers, namely observations with the absolute value of the residuals much greater than other residuals so that it will affect the regression model formed. Outliers are cases or data that have unique characteristics that look very different from other observations and appear in the form of extreme values, both for a variable [1]. There are three types of outliers according to [2], namely outliers in the dependent variable or in the y direction (vertical outliers), outliers in the independent variable or in the x direction (good leverage point), and outliers in the x and y directions (bad leverage point). The presence of outliers can cause large residuals. Therefore, another method is needed to deal with outliers, namely the Robust Regression Method.

Robust regression is an important tool for analyzing data contaminated by outliers. Robust regression is used to detect outliers and gives results that are resistant to outliers [3]. MM estimation (Method of Moment), introduced by [4]. This method combines S estimation (high breakdown point estimate) and M estimation. The MM-estimation has the advantage that it can be used for data detected as outliers in the independent and dependent variables.

The purpose of this study is to overcome outliers in the stock price data of PT. Medco Energi Internasional Tbk. with the exchange rate of the rupiah against the dollar using the M-estimate, in order to obtain a regression model that is free from the effect of outliers.

3. METHOD

3.1 Regression Analysis

In statistics, one of the techniques commonly used in analyzing the relationship between two or more variables is regression analysis, because basically changes in the value of a variable do not always occur by itself, it can be caused by changes in other variables related to the variable. Regression analysis is also one of the statistical tools used in decision making which is widely used in the construction of mathematical models. The rapid development of science requires a reliable mathematical model that will facilitate the process of identifying key variables, forecasting, as well as in designing a simulation project [5].

3.2 Simple Linear Regression Analysis

Regression analysis is an analysis of the dependence of one or more independent variables on one dependent variable, with the aim of predicting or predicting the average value of the population based on the values of the independent variables. Regression analysis used to predict one dependent variable based on one independent variable is called simple regression analysis [6].

3.3 Multiple Linear Regression Model

Functional relationship or causal relationship between two or more variables expressed in the form of a linear function in general can be expressed in the form of mathematical equations discussed in regression analysis. For a linear functional relationship, it can be formulated in the form of a regression equation as follows:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_K X_{iK} + \varepsilon_i \quad ; i = 1, 2, \dots, n \dots\dots\dots(1)$$

where: Y_i : dependent variable, X_{iK} : independent variable, β_0 : intercept, β_1, \dots, β_k : regression coefficients, ε_i : error [7].

3.4 Outlier

In general, outlier data or also known as extreme data is data that is different from other data in a result, the possibility of the value being too large (larger than observations in general) or too small. An outlier is an oddity and indicates a distinctive point compared to other observations. Therefore, it is necessary to examine carefully, it is possible that the reason for the oddity can be known and has a major effect on the regression coefficient [8].

The presence of pencils in the result data will interfere with the data analysis process and should be avoided in many ways. In with regression analysis, outlier data can cause the following things:

1. large residual of the formed model or $E[\varepsilon] \neq 0$.
2. The variance in the data becomes larger.
3. Interval estimates have a wide range.

3.5 Robust Regression

Robust regression procedures are designed to reduce the effect of outliers that have a high impact if the OLS method is used. Therefore, robust regression procedures tend to ignore residuals associated with large outliers [9]. Besides being insensitive if there are cases of outliers, the robust regression procedure has an efficiency level equal to 90% -95% compared to the OLS method if it is

under a normal distribution. This robust regression was developed by Rousseeuw and Leroy in 1987.

Robust regression is intended to accommodate data oddities, as well as eliminate the identification of outlier data and is also automatic in tackling outlier data. This robust regression analysis does not make the model error normal, but the model produced by this method has a higher level of accuracy than the model produced by the OLS model [10]. In detecting outliers, the robust regression method that is often used is Huber estimation M, estimation with Breakdown Point, and a combination of the two methods.

If the data is contaminated with outliers in the independent variable (X), the M estimate may not work well. Estimation M cannot identify bad observations, which means it cannot distinguish good leverage points and bad leverage points.

To overcome this, high breakdown estimation is needed. One estimate that has a high breakdown point value is the S estimate. The form of the S estimator is [3]:

$$\beta_s = \arg \min_{\beta} \hat{\sigma}_S(e_1, e_2, \dots, e_n) \dots\dots\dots(2)$$

with

$$\hat{\sigma}_S = \sqrt{\frac{n \sum_{i=1}^n (e_i^2) - (\sum_{i=1}^n e_i)^2}{n(n-1)}} \dots\dots\dots(3)$$

M estimation will maintain robustness by overcoming vertical outliers, namely outliers contained in the dependent variable (Y). Estimator M which minimizes the function (objective function) of the residual. The estimator M can be written as follows:

$$\min_{\beta} \sum_{i=1}^n \rho(e_i) = \min_{\beta} \sum_{i=1}^n \rho(y_i - \sum_{j=0}^k x_{ij} \beta_j) \dots\dots\dots(4)$$

Estimation Method Of Moment (MM) combines the estimation of High Breakdown Point and statistical efficiency [4].

3.6 Shares

Shares can be defined as a sign of participation or ownership of a person or entity in a company or limited liability company. The form of shares is a piece of paper that explains that the owner of the paper is the owner of the company that issued the securities. The portion of ownership is determined by how much investment is invested in the company [11]. Stocks provide returns in the form of dividends, which are usually paid once a year, and capital gains (an increase in stock prices in the market). Companies that lose will not distribute dividends and if the company does not promise growth, what investors will get is capital loss or a decrease in stock prices in the market.

3.7 Rupiah Exchange Rate

Currency exchange rate is the price of a country's currency against the currency of another country used in conducting trade between the two countries where the value is determined by the supply and demand of the two currencies. The currency of a country can be exchanged or traded with the currency of another country in accordance with the exchange rate prevailing in the currency market or often referred to as the foreign exchange market. With changes in economic and socio-political conditions that occur in a country, the exchange rate of a country's currency against other countries' currencies can change substantially. The currency of a country is said to experience appreciation if its exchange rate relative to the currencies of other countries has increased. On the other hand, the currency of a country is said to be depreciating if its exchange rate relative to the currency of another country has decreased. An upward adjustment or increase in the exchange rate of a currency made by the central bank is called a revaluation. Meanwhile, downward adjustment or decrease in currency exchange rates made by the central bank is called devaluation [12].

4. RESULT AND DISCUSSION

The data used in this study is the closing data of the rupiah exchange rate against the US dollar which is denoted by Y

- Parameter Estimation

Table 1 Estimation of RUIS and MEDC Stock Parameters Against Rupiah Exchange Rate

Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	1.414.798	0.44769	31.60	<.0001
ruis	1	0.00088548	0.00148	0.60	0.5577
medc	1	-0.00055299	0.00044732	-1.24	0.2332

From testing the classical assumptions of linear regression analysis, statistical tests can be carried out with the following hypotheses:

H_0 = there is no effect of stock prices on the rupiah exchange rate on the dollar

H_1 = there is an effect of stock prices on the rupiah exchange rate on the dollar

In Table 1. It can be seen that the value of $t_{count} < \alpha$ (0.05) it can be concluded that H_0 is rejected or there is an influence of stock prices on the rupiah exchange rate on the dollar.

The equation model formed from the estimation of these parameters is:

$$\hat{y} = 14.14798 + 0.00088548x_1 - 0.00055299x_2 + \varepsilon \dots \dots \dots (5)$$

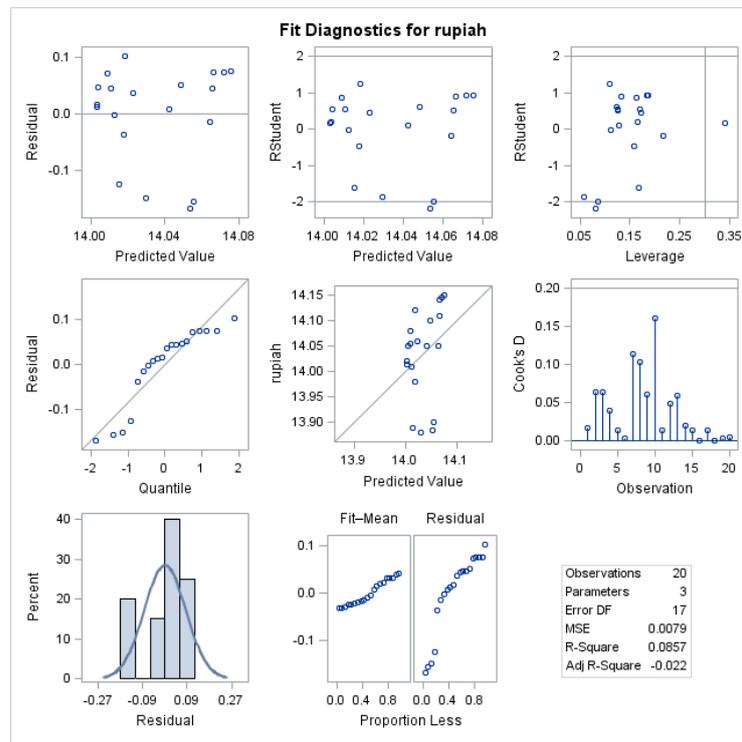


Figure 1. Plot of Residual MKT Method Contains Outliers

Based on Figure 1. it can be seen that there are 20 observational data with 3 parameters where there are outliers in the rupiah exchange rate data against the dollar with RUIS and MEDC stock price data.

Because the data contains outliers, the regression model parameters are estimated using the M-estimation robust regression method to overcome the problem of outliers and produce a better model.

- **Robust Regression Model with M-Estimated**

Table 2. Output Results Summary Statistics

Summary Statistics						
Variable	Q1	Median	Q3	Mean	Standard Deviation	MAD
Ruis	276.0	293.0	303.0	289.8	143.915	163.086
Medc	627.5	672.5	715.0	669.3	476.355	630.106
rupiah	139.950	140.500	141.050	140.345	0.0880	0.0815

Based on Table 2. It can be seen that the data is 20. The median or median is a measure of data concentration, meaning that the data is centered on the middle value.

The standard deviation value in statistics is a measure to see the deviation distance of the data points measured from the average value of the data. The greater the value of the standard deviation of a data, the more diverse the data will be.

The output results show that the variables RUIS, MEDC and the rupiah exchange rate have a fairly high standard deviation, meaning that the data is not too diverse. However, of the three data, MEDC stock has the most diverse data because the value of the standard deviation is the largest

Table 3. Parameter Estimation Results Using M-Estimated on Data Containing Outliers

Parameter Estimates							
Parameter	DF	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	1	138.024	0.1761	134.572	141.476	6139.67	<.0001
ruis	1	0.0023	0.0006	0.0012	0.0034	15.59	<.0001
medc	1	-0.0006	0.0002	-0.0009	-0.0002	11.00	0.0009
Scale	1	0.0322					

The equation model formed from the estimated parameter values is:

$$\hat{y} = 13.8024 + 0.0023x_1 - 0.0006x_2 + \varepsilon \dots \dots \dots (6)$$

Based on Table 3. It can be seen that the standard error value of the MKT method is greater than the M-Estimation. This indicates a better M-estimate for data containing outliers.

5. RESULT AND CONCLUSION

Based on the results of the research that has been done, it can be concluded:

1. M-estimation is one of the estimates in robust regression that can be used to solve the problem of data containing outliers.
2. The robust regression model formed from the M-estimation is:

$$\hat{y} = 13.8024 + 0.0023x_1 - 0.0006x_2 + \varepsilon$$

3. Based on the significance test of the parameters carried out, namely the F-test and T-test, it was found that there was an effect of the value of the stock price on the exchange rate of the rupiah against the US dollar.

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