Antimicrobial activity of the combination of red galangal (Alpinia purpurata K. Schum) and cinnamon (Cinnamomum burmanii) essential oils on Escherichia coli and Staphylococcus aureus bacteria

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Abstract. Essential oils from spices such as red galangal and cinnamon are known to have antimicrobial activity that is strong enough against pathogenic and food destroying bacteria, so it has the potential to be developed as a preservative, especially in food. High antimicrobial activity is generally obtained at high concentrations, which can affect sensory acceptance when applied to food. One way to overcome this problem is to combine the use of essential oils. This study aims to determine the effect of the ratio of the combination of red galangal and cinnamon essential oils to its antimicrobial activity on Escherichia coli and Staphylococcus aureus bacteria. The research was carried out with an experimental method which was analyzed descriptively. Antimicrobial activity testing was carried out by the agar diffusion method and contact method to determine the inhibition growth of E. coli and S. aureus bacteria. The treatment consists of 5 ratios combination of red galangal and cinnamon essential oils, which were 1:0, 0:1, 1:1, 1:2, and 2:1 (v/v). The results showed that the ratio of the combination of red galangal and cinnamon essential oils showed a strong effect on antimicrobial activity towards E. coli and S. aureus. The combination of essential oil at 1:1 (v/v) ratio showed the highest antimicrobial activity against E. coli which was 20.5 mm of inhibition zone, while toward S. aureus was 21.25 mm inhibition zone (strong activity); and could reduce the total test bacteria by reducing 16.85% of E. coli and 21.69% of S. aureus bacteria after 24-hour length incubation.

1. Introduction
Until now, the use of hazardous chemicals in food preservation is still a problem in Indonesia. According to [1], there were still many food products in the community that contained dangerous chemicals that were misused as food additives, in which 162 samples contained borax, 110 samples contained Rhodamine B, 228 samples contained formaldehyde, and four samples contained Methanal Yellow. One alternative to overcome this problem is to use natural antimicrobials as food preservatives that are safe for consumption. It provides an opportunity for the use of natural antimicrobial ingredients such as essential oils from spices. Essential oils are one of the secondary metabolites that are volatile and composed of several components that are predominantly from terpenoids compound. Essential oils are organic compounds obtained from the plant secondary metabolites, where the chemical composition of essential oils of each ingredient depends on the type of plant, the area where it grows, climate, and the plant parts that are taken by oil [2]. Research on the antibacterial activity of various types of spices has been carried out. Spices and several types of plants
empirically have antibacterial activity and traditionally are also widely used as alternative treatments. Several studies on the antibacterial activity of plants, both in the form of extracts and essential oils, show that many plants have antibacterial activity against pathogenic bacteria and plant-destroying substances [3].

Various research results and reviews have reported antimicrobial activity of spices essential oils, such as ginger [4], galangal [5], red ginger [6], and other herbs. Red galangal is a type of spice from the family Zingiberaceae, while cinnamon is a type of Lauraceae family that grows in tropical and subtropical regions in Indonesia such as Jambi, West Sumatra, DI Yogyakarta, Aceh, and West Java. The part of the plant from red galangal (*Alpinia purpurata* K. Schum) that is often used is the rhizome part. Galangal rhizome contains essential oils consisting of methyl-cinnamate, cineol, camphor, δ-pine, galangin, and eugenol [6]. In addition, the red galangal rhizome (*A. purpurata* K. Schum) contains flavonoid compounds, kaempferol-3-rutinoside and kaempferol-3-olicruronide [7]. [8] explained that galangal plants also contain flavonoid compounds, phenols, and terpenoids which can be used as basic ingredients for modern medicines. [4] states that red galangal contains essential oil than white galangal. *Cinnamomum burmannii* (cinnamon) is one type of the Lauraceae family. This plant is widely found in sub-tropical and tropical regions. Research on essential oils from *C. burmannii* from Guangzhou, China conducted by [9], reported that the major components of essential oils contained were trans-cinnamaldehyde (60.72%), eugenol (17.62%) and coumarin (13.39%). According to [10] the oil of *Cinnamomum zeylanicum* Blume showed strong antimicrobial activity against 21 bacteria and 4 Candida species.

The use of spice essential oil as a food preservative is still very limited because of its initial function as a flavoring agent, which is only used at low concentrations. If it is to be used as a preservative, the concentration must be increased to obtain the same antimicrobial effect on food, so that when applied will generally affect the taste, aroma, and level of sensory acceptance [11]. According to [6] antibacterial activity of the combination of red galangal and red ginger essential oils at a concentration ratio of 1:1 (v/v) showed the best effectiveness against Gram-positive bacteria rather than Gram-negative, with a synergistic effect on *B. cereus*, an additive effect on *E. coli* and *S. Typhimurium*, as well as indifferent effects on *P. aeruginosa*. The combination of essential oils shows bacteriostatic effects on all test bacteria after a 24-hour incubation period and has the potential to control pathogenic and food destroying bacteria.

Considering the large potential of red galangal and cinnamon essential oil from local Indonesia as an antimicrobial to be developed as a natural food preservative, this study aims to determine the effect of a combination of red galangal and cinnamon essential oils on antimicrobial activity towards pathogen bacteria represented by *E. coli* and *S. aureus*.

2. Material and methods

2.1. Materials

The main ingredient used was 6-8 months red galangal rhizome (*Alpinia purpurata* K. Schum), and cinnamon (*Cinnamomum burmannii*) obtained from the Indonesian Spice and Medicinal Crops Research Institute (ISMCRI), Bogor, Indonesia. Red galangal and cinnamon essential oil was obtained by steam distillation. Bacterial cultures of *E. coli* and *S. aureus* tested a 24-hour incubation period was prepared in a physiological NaCl solution, then standardized with a standard McFarland solution no. 0, 5 (equivalent to 1.5 x 10^5 CFU/mL).  

2.2. Extraction of Red Galangal and Cinnamon Essential Oil

Fresh red galangal rhizomes and cinnamon washed thoroughly. The raw material was separately thinly sliced and dried in a dyer box at 40-50°C, for 7 hours. The dried material was heated in a steam distillation unit at 150°C for 6 hours. The distillate obtained was separated from the water phase using Na$_2$SO$_4$.  

2.3. Phytochemical Analysis [12]

The yield of essential oils is determined based on the comparison of the volume of essential oils obtained. The yield is expressed in percent.
The yield of essential oil = \frac{\text{essential oil mass}}{\text{sample mass}} \times 100\%

2.4. Organoleptic Observation

Organoleptic observation of essential oils was by looking at the level of color or clarity.

2.5. pH measurement [12]

The pH meter was calibrated with pH 4 and seven buffer solution. Then the electrode was rinsed with distilled water and dried — samples of 5 ml essential oil and mixed with 25 ml of distilled water, then shaken until homogeneous. Then the electrode was dipped into the sample, and the pH value is read on the pH meter screen.

2.6. Preparation of Testing Bacteria

Bacterial culture prepared on Mueller Hinton Broth (MHB) media. Pure cultures dissolved in 0.85% NaCl solution was standardized with a 0.5 McFarland solution using mixed absorbance test using a spectrophotometer at a wavelength of 625 nm and produced an absorbance range of 0.08-0.1. The number of bacteria according to the McFarland 0.5 standard was estimated to be 1.5 x 10^8 CFU/mL.

2.7. Antimicrobial Test with Agar Diffusion Method

A total of 20 mL of sterile MHA media was poured into a petri dish and allowed to solidify, then added 20μL of liquid bacterial test culture using the swab method. After that in each bacterial cup made a well with a diameter of 6 mm. The combination of red galangal and cinnamon essential oil pour into the well with a ratio of 1:0 (A), 0:1 (B), 1:1 (C), 1:2 (D), and 2:1 (E), tetracyclin-HCl 1% used as positive control, and ethanol 96% as negative control. The culture was incubated at 37°C for 24 hours. Observations were made on inhibitory zone diameter in E. coli and S. aureus bacteria. All treatments were repeated two times with Duplo analysis.

2.8. Antimicrobial Test with Contact Method

The red galangal and cinnamon essential oils 1% solution were then taken as much as 40 μl and then added 4 ml of sterile Mueller Hinton Broth (MHB) and 15 μl test bacteria of 10^8 CFU/ml into the test tube, followed by incubation at the temperature 37°C for 18-24 hours. The culture was then grown in an Eosin Methylene Blue (EMB) agar and Mannitol Salt Agar (MSA). The culture was incubated at 37°C for 18-24 hours, and some colonies growth was observed.

The research method used was an experimental method which was analyzed descriptively. Antimicrobial testing was carried out with five treatment combinations that were repeated twice. The treatment combination consisted of a combination of red galangal essential oil and cinnamon essential oil at a ratio: A (1:0), B (0:1), C (1:1), D (1:2), and E (2:1) (v/v).

3. Results and discussion

3.1. Physical Characteristics of Red Galangal and Cinnamon Essential Oils

The yield of essential oils was determined by comparing the mass of essential oils with dry sample masses. The results showed that in this study the yield of red galangal essential oil was 0.30%, while the yield of cinnamon essential oil was 1.21%. [6] stated that the yield of red galangal essential oil obtained 0.06%; so the yield of red galangal essential oil obtained in this study was higher compared with other research.

The quality of essential oils was influenced by several factors, ranging from the selection of varieties, conditions of raw materials, equipment, methods of refining, and how to store products. If all these requirements were not fulfilled, the results of the essential oil products obtained would not be suitable. Some factors that influence the quality of essential oils included: raw materials, post-harvest handling, production, and storage process [5], [7].

Based on the observation, the color of red galangal essential oil was bright yellow and has a distinctive aroma of red galangal (Fig. 1). This was due to the presence of the main components,
namely terpenoids. According to [13], 1% of essential oils are greenish yellow consisting of 48% methyl-cinnamon, 20-30% cineol, eugenol, 1% kamfer, galangin, and others. The terpenoids contained in plants are usually used as aromatic compounds that cause odor in eucalyptus, flavoring cinnamon, cloves, ginger and yellowing of flowers.

Cinnamon essential oil had a deep yellow color and had a distinctive cinnamon aroma (Fig. 1). This was due to the presence of major components in cinnamon essential oils, namely cinnamaldehyde (65-80%) and eugenol (5-10%) [14]. It was in accordance with SNI 06-3734-2006 stating that the quality standard of cinnamon essential oil was dark yellow to brownish yellow and has a distinctive aroma of cassia Indonesia.

**Figure 1.** Red galangal (A) and cinnamon (B) essential oil

Based on the observations, the pH of red galangal essential oil was 3.7, while the pH of cinnamon essential oil was 2.5 so it can be said that red galangal and cinnamon essential oils had acidic pH. According to [7], *E. coli* and *S. aureus* bacteria are still able to grow and survive at low pH conditions up to pH 2, so that it can be seen that the antimicrobial effects produced by red galangal and cinnamon essential oil come from the phytochemical compounds it contains. Red galangal and cinnamon essential oil was widely used in medicine, but until now there was no quality standard governing the specifications. [10] stated that the physical properties of essential oils such as specific gravity, refractive index, optical rotation and solubility were largely determined by the chemical composition of the oil. The greater the molecular weight of a compound, the greater the specific gravity and refractive index. According to Rialita [7], the characteristics of red galangal essential oil had a bright yellow color, the specific gravity of 0.8947 gr/mL, a refractive index of 1.4956, an acid number of 2.06. Whereas according to SNI: 06-3734-2006 the characteristics of cinnamon essential oil had a brownish yellow color, specific gravity was 1.008 - 1.030 gr/mL, and the refractive index is 1.559 - 1.595.

3.2. Antimicrobial Activity of Combination of Red Galangal and Cinnamon Essential Oil Against *E. coli* and *S. aureus* Bacteria

The combination of red galangal and cinnamon essential oils at all ratios had strong antimicrobial activity against testing bacteria (Table 1). Antimicrobial activity on *E. coli* showed an average inhibition zone of 12.75 - 20.5 mm while in *S. aureus* was 9.75 - 21.25 mm. Tetracycline 1% (v/v) as a positive control showed the average microbial activity of 23 mm inhibitory zone on *E. coli*, and on *S. aureus* was 33.17 mm, while alcohol 96% (v/v) as solvent (negative control) did not show antibacterial activity.

| Testing Bacteria | The average diameter of the inhibitory zone (mm) | Control (+) | Control (-) | 1:0 | 0:1 | 1:1 | 1:2 | 2:1 |
|------------------|-----------------------------------------------|-------------|-------------|-----|-----|-----|-----|-----|
| *E. coli*        |                                               | 23.0±1.56   | 0±0         | 12.75±4.60 | 17.25±0.35 | 20.50±0.71 | 18.50±2.12 | 18.50±0.71 |
| *S. aureus*      |                                               | 33.17±1.92  | 0±0         | 9.75±1.77  | 15.50±2.83  | 21.25±5.30 | 16.0±2.12  | 14.75±0.35 |
The combination of red galangal and cinnamon essential oils in this study showed high antimicrobial activity with a range of 12.75 - 21.25 mm. According to [15], the antimicrobial activity of plant extracts can be grouped based on the inhibition diameter of the agar media into three categories, namely: high (> 11 mm), medium (> 6 mm - <11 mm), and low (<6 mm).

Antimicrobial activity of the combination of red galangal and cinnamon essential oils against *E. coli* bacteria showed a strong inhibitory zone of 12.75 - 20.5 mm. A single treatment of essential oil showed strong antimicrobial activity, namely in red galangal essential oil of 12.75 mm, and on cinnamon essential oil of 17.25 mm. Antimicrobial activity of single cinnamon essential oil was greater than red galangal essential oil. This caused by the active component found in cinnamon essential oil which was effective in inhibiting test bacteria. The main component of cinnamon essential oil was cinnamaldehyde which was a phenolic group while red galangal essential oil was from terpenoids. Based on the observations, it was shown that phenolic groups were easier to enter phospholipids in bacterial cells so that they can interfere with the normal function of these cells than terpenoids.

The combination of essential oils at a ratio of 1:1 (v/v) show the highest inhibition zone of 20.5 mm. This was higher than the combination ratio of 1:2 and 2:1 (v/v), that was equal to 18.5 mm. The results of the combination of essential oils produce a greater inhibition zone diameter than a single essential oil. This shows that the combination of red galangal and cinnamon essential oils produces a synergistic effect on *E. coli* bacteria. The main components of red galangal essential oil consist of hydrocarbon monoterpenes and oxygenated monoterpenes, while cinnamaldehyde and eugenol were essential for cinnamon essential oils as antimicrobial compounds. With this combination, the active components of each essential oil work to strengthen each other to inhibit *E. coli* bacteria.

Antimicrobial activity of the combination of red galangal and cinnamon essential oils showed strong inhibitory zone (9.75 - 21.5 mm) against *S. aureus* bacteria. In the testing of essential oils singly showed strong antimicrobial activity, namely the red galangal essential oil of 9.75 mm, while the cinnamon essential oil was 15.5 mm. This was similar to the testing of *E. coli* bacteria that single cinnamon essential oil was more effective in inhibiting the bacteria than red galangal essential oil. The combination of essential oil at a ratio of 1:1 (v/v) show the most effective inhibitory effect on *S. aureus* bacteria, which was 21.25 mm. This was greater than the 1:2 and 2:1 ratio (v/v) which produced 16 mm and 14.75 mm inhibition zone. The results of the combination of essential oils of red galangal and cinnamon produce a diameter of inhibitory zones larger than single essential oils so that it can be said that the combination of essential oils shows a synergistic effect also.

**Figure 2.** The diameter of the inhibitory zone in *E. coli* (a) and *S. aureus* (b)

Based on observations of both *E. coli* and *S. aureus* bacteria, it turns out that cinnamon essential oil had a greater inhibitory power compared to red galangal essential oil. This shows that the bioactive content of cinnamon essential oil was very effective in inhibiting Gram-negative and Gram-positive bacteria. The compounds that act as antimicrobials in cinnamon essential oils were phenylpropanoid (such as eugenol and cinnamaldehyde), besides that, they also contain terpenoid hydrocarbon compounds (such as α-pinene and limonene). These compounds can accumulate in the lipid tissue of bacterial cell membranes, and disrupt the structure and function of cell membranes caused by expansion (swelling) of cell membranes and changes in the permeability of bacterial cell membranes [16].
The main components of red galangal essential oil consist of monoterpenes hydrocarbon compounds (β-pine) of 9.04% and oxygenated monoterpenes (eucalyptol and 4-Alllylphenyl acetate) of 54.59% [5]. These components were thought to be compounds that have antibacterial activity. Monoterpenes were formed from two isoprene units that make up ten carbon atoms. Monoterpene was a major component of essential oils that play a role in creating smell and taste [2]. The major component of cinnamon essential oil was cinnamaldehyde and eugenol which determine the quality of the oil. Cinnamaldehyde compounds belonging to the phenylpropanoid group were derivatives of phenol compounds, where the phenol compound also plays an important role in antioxidant activity [4]. Based on the research of [3] the total phenol content of cinnamon extract (Cinnamomum burmannii) was 11.9 g GAE / 100 g dry weight. According to SNI 06-3734-2006 [17], cinnamon oil has a specific gravity of 1.008 - 1.030, the refractive index of 1.559 - 1.595, solubility in 70% ethanol (1:3 clear), and its main component was sinemaldehyde. [5] also stated that minor components could act as a critical or determinant factor for the power of antimicrobial activity, because of the possible synergistic effect among various components of essential oil. Antimicrobial phenolic compounds work through several mechanisms, causing cellular leakage of components, damaging enzymatic mechanisms for energy production and metabolism, altering nutrient uptake and electron transport [18]. Flavonoids were the largest group of phenol compounds; phenol compounds have effective properties to inhibit the growth of viruses, bacteria, and fungi. Flavanoid compounds were generally antioxidants, and many were used as a component of raw materials for medicines. Flavonoid compounds and their derivatives had two specific physiological functions, namely as a chemical to overcome disease attacks (as antibacterial) and anti-virus for plants. The mechanism of action of flavonoids as antimicrobials by forming complex compounds with extracellular proteins and dissolved can damage the bacterial cell membrane and was followed by the release of intracellular compounds [19].

Terpenoid compounds can inhibit growth by interfering with the formation of membranes and or cell walls, membranes or cell walls were not formed or formed imperfectly. The mechanism of terpenoid as an antimicrobial was reacting with porin (transmembrane protein) on the outer membrane of the bacterial cell wall, forming a strong polymeric bond which causes damage to porins [4]. [13]. The results showed that the combination of red galangal and cinnamon essential oil at a ratio of C (1:1) was equally effective in inhibiting Gram-negative (E. coli) and Gram-positive (S. aureus) bacteria, so it could be stated that terpenes and phenolics could damage both bacterial test cells. It was proven that the combination of red galangal and cinnamon essential oils with low concentrations at C (1:1) ratio results in a high inhibitory zone diameter in E. coli of 20.5 mm, whereas in S. aureus that was 21.25 mm. [13]

Explains that derivatives of terpenoids such as 1,8-cineole, -caryophyllene, -pinene, geraniol, neral, Geraniol, and camphor were thought to be involved in various mechanisms of damage to the bacterial cytoplasmic membrane, coagulating cell components and disrupting the Proton Motive Force (PMF). Antibacterial compounds of essential oils such as eugenol, thymol and carvacrol can cause cell membrane damage, release intracellular ATP and other components. The combination of various components of essential oils that are weak or moderate can produce synergistic or mutually reinforcing effects [20]. Essential oils from plants consist of a variety of compounds, so the use of a combination of red galangal and cinnamon essential oils can produce higher antimicrobial activities with low concentrations and can be sensory acceptance.
The results of antimicrobial activity test against *E. coli* by contact method can be seen in Fig. 3. The treatment of single red galangal essential oil was the ratio of A (1:0) could reduce testing bacteria by 5.24%, while the treatment of cinnamon essential oil singly, i.e., the ratio of B (0:1) can reduce 17.47% of the total test bacteria. This shows that cinnamon essential oil was more effective in inhibiting the growth of *E. coli* bacteria compared to red galangal essential oil. The main components of cinnamon were cinnamaldehyde (92.0%), α-Copaene (4.10%), and 3-phenyl-2-propenylacetate (2.07%). Cinnamaldehyde were a phenylpropene group that had a phenolic group. The activity of cinnamaldehyde was better than eugenol as an antibacterial. Cinnamaldehyde was able to enter phospholipids in bacterial cells so that they can bind to proteins that can interfere with the normal function of these cells. Cinnamaldehyde can also inhibit bacterial growth without destroying the outer membrane and was able to enter the periplasm to the inside of the cell [10].

The combination of red galangal and cinnamon essential oil at a ratio of C (1:1) can reduce *E. coli* number which was quite high at 16.85%. While the results of the reduction in the ratio of D (1:2) was 4.01% and at the ratio E (2:1) was 0.69%. The greater reduction in the presentation of the amount of reduction concludes the better the combination of essential oils. *E. coli* bacteria were gram-negative bacteria that had thin peptidoglycan which was 5-10% Gram-negative outer membrane consists of three layers, namely lipopolysaccharide (LPS), lipoprotein, and phospholipid, with porins formed from proteins. Porin was a channel that can be passed by several molecules [18]. This outer membrane serves as an antibiotic barrier, digestive enzymes, and drought conditions, but cannot be a barrier to all substances. These bacteria were not pathogenic, but some strains produce toxins that can cause hyper-secretion in the small intestine [10].

The results of antimicrobial activity test against *S. aureus* with the contact method could be seen in Fig.4. The results showed that the treatment of single red galangal essential oil at ratio A (1:0) could reduce 30.53% number of *S. aureus*, while in the treatment of single cinnamon essential oil at ratio B (0:1) could reduce 33.67% of bacteria. This was in line with the results of qualitative testing which showed cinnamon essential oil more effectively inhibits the growth of *S. aureus* bacteria than red galangal essential oil. The greater reduction in the presentation of the amount of reduction, the better it was to inhibit the bacteria. The percentage of the reduction of the two types of essential oils in *S. aureus* bacteria was greater than that of *E. coli*. Thus the red galangal and cinnamon essential oil was effective in inhibiting the growth of *S. aureus* bacteria.
The results showed that the combination of red galangal and cinnamon essential oil at the ratio of C (1:1) could reduce 21.69% of *S. aureus*, while at ratio D (1:2) can reduce 17.43%, and at the ratio E (2:1) was 10.76%. In general, the combination of essential oils, either single or mixed showed antimicrobial activity that was stronger against gram-positive bacteria (*S. aureus*) than gram-negative bacteria (*E. coli*). This was also explained by previous studies that gram-negative bacteria were more resistant to essential oils than gram-positive bacteria [21]. [22]. Essential oils can work better on Gram-positive bacteria than Gram-negative bacteria because Gram-negative bacteria had thicker and more complex cell walls. Cell walls in Gram-negative bacteria such as *E. coli* contain many polysaccharides, so the walls were harder and limit the diffusion ability of essential oil hydrophobic compounds. Whereas in Gram-positive bacteria such as *S. aureus* had thin cell walls because they contain fewer liposaccharides to facilitate the hydrophobic compounds of essential oils to diffuse into bacterial cell membranes [11].

According to [18], essential oils were generally effective against Gram-positive bacteria compared to Gram-negative bacteria. The outer membrane of Gram-negative bacteria acts as a barrier to the entry of compounds that were not needed by cells, including bacteriocins, enzymes, and hydrophobic compounds. [23] explained that to achieve the target antimicrobial compounds can penetrate lipopolysaccharide (LPS) from the cell wall. Hydrophilic molecules were easier to pass LPS than those that were hydrophobic. Gram-positive bacteria did not have LPS, so hydrophilic and hydrophobic functions (such as essential oils) can diffuse into cells.

The main component of red galangal essential oil was 1.8-cineole. According [6], the main component of red galangal essential oil was 1.8-cineole by 20.79% which was an oxidized monoterpenic compound, while chavicol was 14.51% which belongs to the phenylpropane group. [24] explained that 1.8-cineol compounds and their isomers in addition to being a flavoring component of galangal rhizomes also have broad-spectrum antimicrobial activity, while chavicol compounds and their isomers were known to have various biological activities such as anti-mold, anti-tumor, anti-inflammatory, anti-oxidants, and xanthinoxidase inhibitors. The main active component in cinnamon was cinnamaldehyde, and oxidized monoterpenes were thought to be strong antibacterial. [25] stated that the antimicrobial activity of hydrocarbon components was lower than that of oxidized components. However, according to [5] minor components can act as a critical or determinant factor for the power of antimicrobial activity, because of the possible there was a synergistic effect among various components that form essential oils.

Figure 4. Antimicrobial activity against *S. aureus* in the contact method
The results testing of antimicrobial activity of the combination of red galangal and cinnamon essential oils from qualitatively and quantitative methods at the ratio of C (1:1) showed the similar strong activity in inhibiting *E. coli* and *S. aureus* bacteria growth. So it can be concluded that there were several likely to be responsible as antimicrobials of essential oils. The suspected compounds were phenols, flavonoids, and terpenoids.

4. Conclusion
The red galangal essential oil produced of 0.30% yield, pH 3.7 and had a bright yellow color, while the cinnamon essential oil had 1.21% yield, pH 2.5 and had a brownish yellow color. The ratio of the combination of red galangal and cinnamon essential oils had a strong influence on antimicrobial activity.

The ratio of the combination of red galangal and cinnamon essential oil at a concentration of 1% with a ratio of 1:1 (v/v) shows strong antimicrobial activity against *E. coli* and *S. aureus* bacteria, i.e. each inhibition zone was 20.5 and 21.25 mm (strong category), and can reduce total bacterial test by 16.85% to *E. coli* bacteria and 21.69% to *S. aureus* bacteria compared to controls.

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