Antibacterial activity of infused peel of kaffir lime, manurun banana, and pineapple against the number of *Staphylococcus aureus* and *Escherichia coli* colonies

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Abstract. The rind of the citron (*Citrus hytrix DC*), manurun banana (*Musa paradisiaca Linn*), and pineapple (*Ananas comosus L. Merr*) fruit contains antibacterial compounds of flavonoids, alkaloids, and tannins, which have the potential to be used as alternative antiseptic ingredients. This study aimed to analyze the antibacterial activity of kaffir kaffir lime, manurun banana, and pineapple peel-infused water on the number of *Staphylococcus aureus* and *Escherichia coli* bacteria colonies. The research design used a post-test-only with control group design. The test treatments were an infusion of three types of fruit peel at concentrations of 25%, 50%, 75%, and 100%, 70% alcohol, and distilled water. The results of the analysis of research data using the ANOVA test and Duncan's post-hock test (0.05), showed that there were differences in the number of test bacteria in all the fruit peel infusions tested. The least number of bacteria was in the kaffir lime peel infusion treatment. The conclusion is that there are differences in the antibacterial activity of the infusion of the kaffir lime, manurun banana, and pineapple peel infused water on the number of *Staphylococcus aureus* and *E. coli* bacteria colonies; 100% kaffir lime peel infused water had a better effect on reducing the number of tested bacterial colonies than other tested infusion treatments (p < 0.05).

Keywords: fruit peel infused water, kaffir lime, manurun banana, pineapple, number of bacterial colonies, *Staphylococcus aureus*, *Escherichia coli*.

1. Introduction

Bacterial infectious diseases that are transmitted through the skin of the hands are still a health problem, especially for people who live in riverbank areas. Types of *Staphylococcus aureus* (*S.aureus*) and *Escherichia coli* (*E.coli*) bacteria are commonly found and are often found on the skin of the hands. Both types of bacteria are opportunistic normal flora on the human body, *S. aureus* is often associated with respiratory tract infections and *E. coli* causes digestive tract infections [1].

Prevention of infectious disease transmission can be done by washing hands, using antiseptic substances, and rinsing them with clean and running water. The antiseptic ingredient is generally alcohol-based. Alcohol is a bactericidal substance that works by denaturing cell proteins and lysing...
bacterial cells [2-4]. The use of 70% alcohol as an antibacterial agent is effective in reducing the population of bacteria found on the hands [1] but long-term use can irritate the skin of the hands [2-4]. Several innovations in antiseptic products can be developed using herbal ingredients that contain antibacterial secondary compounds and are intended to reduce the use and negative effects of chemical-based drugs.

Biodiversity that exists in the territory of Indonesia produces local plants that can be consumed and used by the community, including fruit plants such as kaffir lime (Citrus hystrix DC), manurun banana (Musa paradisiaca Linn), and pineapples (Ananas comosus L. Merr). The benefits of these fruits have been used by various circles of society, but generally, the skin of the fruit is often disposed of as waste. Several studies have proven the presence of secondary compounds in the three fruits that act as antibacterial substances. The content of secondary compounds in the skin of kaffir lime is flavonoids, alkaloids, and tannins [5]. The content of secondary compounds in the peel of the manurun banana is alkaloids, saponins, tannins, flavonoids, and terpenoids [6]. The active compounds in pineapple peel are bromelain enzymes, flavonoids, saponins, alkaloids, and tannins [7,8].

In the dosage form, extracts from the three plants have been shown to have activity in inhibiting the growth of S. aureus and E. coli bacteria. The ethanol extract of kaffir lime peel has the activity of inhibiting the growth of S. aureus and E. coli bacteria [5]. Manurun banana peel ethanol extract has activity against the growth of E. coli bacteria and gram-negative bacteria Salmonella typhi and Shigella dysenteriae [9,10]; Ethanol extract of raw and ripe banana peel can inhibit S. aureus [11]. The test results of n-hexane and ethanol extract from pineapple peel at a concentration of 0.5%-1.5% are known to be able to inhibit the growth of S. aureus and E. coli [12]. The presence of antibacterial substances in a plant can be developed into herbal preparations including antiseptic preparations. The test results of giving 75% kaffir lime juice when washing hands, have more effectiveness as an antiseptic than 70% alcohol [13]. The results of testing the antibacterial activity of anti-acne cream preparations ethanol extract of kepok banana peel (Musa balbisiana colla) against Propionibacterium acne bacteria: It was found that 30% extract formula had the highest antibacterial activity [14]. The results of the application test of pineapple peel extract as hand wash produced an antibacterial effect against Staphylococcus aureus (inhibition zone of 10.9 mm) and Escherichia coli (inhibition zone of 9.9 mm) [15].

From the research mentioned above, it can be illustrated that the presence of antibacterial substances in the skin of kaffir limes, bananas, and pineapples, which has the potential to be developed as antiseptic preparations. To utilize fruit peel waste that is often found in the community, a study can be carried out to prove the antibacterial activity of the three types of fruit peels against bacteria that are often found on hands. The infusion method was chosen as the herbal preparation being tested because this method is easy to make with water solvent and can be made using simple equipment, so it is easily adopted by the community. The purpose of this study was to analyze the antibacterial activity of infusions of kaffir lime peels, manurun bananas, and pineapples on the number of S. aureus and E. coli colonies. This experimental laboratory research used a posttest-only design with a control group design. The test bacteria were isolates of S. aureus and E. coli, which were pure reculture from hand swab samples of elementary school students at SDN Sungai Lulut Banjarmasin. The treatment groups tested were an infusion of kaffir lime peel, manurun banana peel, and pineapple peel at concentrations of 25%, 50%, 75%, and 100%, respectively; 70% alcohol (positive control) and sterile distilled water (negative control). This research was conducted from October to December 2020, at the Microbiology Laboratory, Faculty of Medicine, University of Lambung Mangkurat.

2. Materials and Methods
2.1. Ingredients
Orange peel (Citrus hytrix DC), manurun banana peel (Musa paradisiaca Linn), pineapple peel (Ananas comosus L. Merr), pure isolates of S. aureus and E. coli bacteria, Nutrient Agar (NA) media, Nutrient Broth (NB) media, 70% alcohol, spirit, sterile distilled water, Mc Farland 1 solution (equivalent to the number of bacteria of 3,108 CFU/ml).
2.2. Production of infused water
Simplicia of the peels of kaffir limes, manurun bananas, and pineapples which had been washed with running water, drained, then sliced into small pieces, dried, and mashed. A total of 100g of Simplicia was dissolved by adding 100 ml of distilled water into the infusion pan and heated for 15 minutes from the time the temperature reached 90°C while stirring. The results of the liquid preparation are immediately filtered using flannel/gauze. Subsequently, a series of dilutions were carried out for each infusion of the test fruit peels with a concentration of 25%, 50%, 75%, and 100% (w/v), and placed into a 10 ml test tube, to be prepared as a treatment test sample. 70% alcohol control and sterile distilled water were also prepared at the same volume.

2.3. Tested bacteria preparation
Pure isolates of S. aureus and E. coli which grew on NA media (37°C, 24 hours) were used as test bacteria isolates. 1 ose of test bacterial isolates were taken aseptically and put into nutrient broth (NB) media from several samples of pure isolates of S. aureus and E. coli. Next, incubation was carried out for 5 hours at 37°C, then homogenized and the turbidity equalized with Mc Farland I standard solution (3x10⁸ CFU/ml). Each suspension of the test bacteria in the NB media in this tube was prepared as a test bacterium.

2.4. Bacterial activity test
The method of testing the antibacterial activity against bacterial culture uses standard culture methods. Each test treatment has been prepared (infusion of the rind of the test plant at various test concentrations, 70% alcohol, and distilled water) and the bacterial test suspension. 0.1 ml of the test bacterial suspension was taken and added to a tube containing 10 ml of the test treatment and homogenized by shaking slowly for about 5 minutes. Next, 0.1 ml of the infusion-bacteria test suspension was taken to be dropped on a petri dish, then a warm NA medium was poured in. The petri dish was shaken slowly and evenly, until the NA medium solidified, after that each test medium was incubated at 37°C for 24 hours. The number of bacterial colonies growing on NA media was calculated using a colony counter.

2.5. Data analysis
The distribution of the research data was analyzed using the normality test with the Shapiro Wilk test and the homogeneity test with the Levene's test; the data obtained in this study were normally distributed and homogeneous. Data analysis to determine differences and compare the effects of all the treatments tested was done using one-way ANOVA and Duncan's posthoc tests at a 95% confidence level.

3. Results
The results of calculating the average number of colonies of S. aureus and E. coli bacteria growing on NA media from all the treatments tested are shown in Figures 1 and 2. The results of data analysis using one-way ANOVA shows that there was a significant difference between all the treatments tested. The results of Duncan's Post-hoc test are in Table 1.
Figure 1. The mean number of colonies of S. aureus bacteria after treatment with kaffir lime, manurun banana, and pineapple peel infusion as well as control treatment.

Figure 2. The mean number of colonies of E.coli bacteria after treatment with kaffir lime, manurun banana, and pineapple peel infusion as well as control treatment.
Table 1. Comparison of the effectiveness of infusion of kaffir lime, manurun banana, and pineapple peel to the mean number of colonies of *Staphylococcus aureus* and *Escherichia coli* based on Duncan's posthoc (α.0.05).

| Treatment                          | The average number of bacteria colonies |
|------------------------------------|-----------------------------------------|
|                                    | *Staphylococcus aureus* | *Escherichia coli* |
| Positive control                   | 29A                       | 36A                 |
| Infusion of kaffir lime peel 100%  | 32A                       | 37A                 |
| Infusion of manurun banana peel 100% | 41B                   | 54B                 |
| Infusion of pineapple peel 100%   | 37B                       | 39A                 |
| Infusion of kaffir lime peel 75%   | 56C                       | 69C                 |
| Infusion of manurun banana peel 75% | 75D                   | 78D                 |
| Infusion of pineapple peel 75%    | 68E                       | 69C                 |
| Infusion of kaffir lime peel 50%   | 74D                       | 88E                 |
| Infusion of manurun banana peel 50% | 94F                   | 98F                 |
| Infusion of pineapple peel 50%    | 86G                       | 88E                 |
| Infusion of kaffir lime peel 25%   | 101H                      | 111G                |
| Infusion of manurun banana peel 25% | 126I                   | 129H                |
| Infusion of pineapple peel 25%    | 115J                      | 116G                |
| Negative control                   | 143K                      | 144I                |

Note: the average value followed by the same letter notification, means that the antibacterial effect is not different mean

Application of kaffir lime, manurun banana, and pineapple peel infused water, as well as 70% alcohol can better reduce the number of test bacteria (*S. aureus* and *E. coli*) than the negative control (aquades). This indicates the presence of antibacterial activity contained in the three tested fruits. The concentration in the smallest treatment was 25% (w/v) of all infusions of the test plants, showing a better effect on decreasing the number of test bacteria than the distilled water treatment. The 70% alcohol treatment had an inhibitory effect on the growth of the test bacteria so that the average number of *S. aureus* and *E. coli* bacteria was obtained at the lowest after 70% alcohol treatment. Alcohol is a bactericidal substance that works by damaging cell membranes and denaturing bacterial cell proteins [4,16]. The 70% of alcohol is an antiseptic that can reduce the number of *S. aureus* and *E. coli* bacteria colonies that are commonly found on hands [1]. Increasing the concentration of fruit peel infusion treatment from the three test fruits, in general, could increase the antibacterial effect and decrease the number of colonies of test bacteria that grew on NA media. Increasing the concentration can increase the solubility and stability of antibacterial secondary compounds in the tested extract preparations, to increase their effectiveness as antibacterial.

The results of the analysis of research data with Duncan’s test (Table 1), obtained the average number of bacteria in several treatments, not significantly different or can be said to have relatively the same and equal effectiveness. In the 100% fruit peel infusion treatment, the equivalent effect was obtained between 100% kaffir lime peel infusion and 70% alcohol in reducing the number of *S.aureus* colonies; while the activity of fruit peel infusion treatment on the number of *E.coli* bacteria which can be equivalent to 70% alcohol, namely 100% kaffir lime and 100% pineapple. The infusion treatments of the three fruit skins of the test plants at concentrations of 75%, 50%, and 25% showed significantly different effects on the number of *S. aureus* bacteria colonies; while the equivalent effect was seen in the treatment of 100% manurun banana peel infusion and 100% pineapple peel infusion. The effect of the infusion treatment on the number of colonies of *E.coli* bacteria, produced several equivalent results, namely infusion of kaffir lime peel fruit with pineapple at concentrations of 100%, 75%, 50%, and 25%. The results of this study can illustrate that kaffir lime peel infusion has better activity in reducing the number of *S. aureus* and *E. coli* bacteria, compared to banana peel and pineapple infusion.
4. Discussion
Based on several references from the phytochemical test results, it was found that the types of secondary compounds were relatively the same in the three tested plants, these compounds were flavonoids, while other types of secondary compounds were relatively different. Different secondary compounds cause differences in antibacterial activity produced by herbal preparations. The activity of secondary compounds as antibacterials contained in a plant plays a role in inhibiting nucleic acid synthesis, inhibiting cell membrane function, inhibiting bacterial cell metabolism, and reducing cell surface tension. Extracts from plants that have more diverse secondary compounds and work synergistically, can provide a stronger antibacterial effect.

The skin of the kaffir lime peel contains secondary compounds such as flavonoids, phenolics, steroids, terpenoids [17,18], coumarin [19]; saponins, polyphenols, terpenoids, and alkaloids; naringin which is the main derivative of flavonoids, as well as phenolic compounds and ascorbic acid (96.7%), in the skin of kaffir limes has a role as a strong antioxidant [20,21]. The peel of the kaffir lime peel contains more diverse secondary compounds than the peel of the banana manurun and the skin of the pineapple, therefore its effectiveness as an antibacterial is better.

The secondary compounds contained in the Manurun banana peel are flavonoids, alkaloids, tannins [22], saponin dan triterpenoid [23]. In general, the tannin content is more in immature banana peels than ripe fruit peels, due to an increase in ethanol, up to 70 times, the ripening process of bananas causes a decrease in tannin content [25,26].

The content of secondary compounds in pineapple peel are flavonoids, saponins, and tannins [27-29]. Bromelain enzyme [30]; polyphenols, flavonoids, and quercetin as derivatives of flavonoids [31]. Other contents in the form of antioxidants are vitamin C, carotenoids, anthocyanins, and bromelain enzymes [32,33]. Bromelain enzymes can be damaged at 40°C [31].

Flavonoids belong to a phenol group, which is an acidic alcohol group that plays a role in denaturing proteins and damaging bacterial cell membranes. The mechanism of action of flavonoids includes inhibiting the topoisomerase II (DNA gyrase) enzyme, an enzyme that is important in the process of DNA replication and transcription along with the nucleic acid intercalation process to form RNA [34-35]. This causes damage to the permeability of the cell wall and bacterial lysosomes. Flavonoids can bind and form complex compounds with extracellular proteins so that they will damage the function of cell membranes followed by the release of intracellular compounds. Flavonoids can inhibit cytochrome C reductase, therefore the metabolic processes and energy biosynthesis of bacterial cell macromolecules are inhibited [34-36].

Saponins are active substances whose surface is similar to detergent, which lowers the surface tension of bacterial cell walls and impairs membrane permeability, thereby interfering with the survival of bacteria. When the surface tension is disturbed, saponins will easily enter cells and interfere with metabolism, causing denaturation of membrane proteins where it can make cell membranes become damaged and lysis [18,31,37,38].

Alkaloids interfere with the peptidoglycan constituent components of bacterial cells, this causes the cell wall layer to not form intact and causes the death of the cell. Alkaloids also have a nitrogen-containing base group as a DNA inter-chelator that will inhibit the bacterial topoisomerase enzyme that plays a role in the process of replication, transcription, and recombination of bacterial DNA [32,40,41,42].

Tannins are toxic and can affect changes in cell membrane permeability and reduce the volume of bacterial cells. Tannins can also inhibit the reverse transcriptase and DNA topoisomerase enzymes so that bacterial cells cannot be formed. Coumarin secondary compounds play a role in damaging cell membranes by forming cell wall pores, causing bacterial cell death [18,37].

Pineapple skin contains the enzyme bromelain which is a proteolytic enzyme that produces catalytic and hydrolysis reactions by breaking peptide bonds in bacterial proteins. This enzyme can hydrolyze proteins and glycoproteins, then lower the surface tension of bacteria, thereby inhibiting growth and killing bacteria [32]. Bromelain can also be obtained from almost all parts of the pineapple plant (Ananas
position of most gram

comosus [L]Merr.) both from the stalk, skin, leaves, fruit, and stems. This enzyme breaks down proteins by breaking peptide bonds and producing simpler proteins [43].

The solvent used in this study was distilled water which has polar characteristics so that only polar or semi-polar secondary compounds can dissolve in water solvents. Alcohol as a positive control has a hydroxyl group that also has polar characteristics. The solubility of a compound in a solvent depends on the groups attached to the solvent. The type of solvent used in the herbal extraction process is influenced by the type of material extracted, as well as the structure and composition of the bacterial cell membrane. Based on their polarity, flavonoids are classified as polar compounds; saponins and phenolic compounds including polar and semipolar compounds [31]. Terpenoids are nonpolar compounds. Polar compounds that are present in plants can be extracted with semi-polar and polar solvents [31,45]

Polar secondary compounds are effective in inhibiting the growth of gram-positive bacteria, penetration of the peptidoglycan layer which is also polar in gram-positive bacteria occurs more easily than non-polar lipid layers. The cell wall of gram-positive bacteria contains polysaccharides (tricossil acid) which is a water-soluble polymer that can function as a positive ion transfer in and out. The soluble nature indicates that the gram-positive cell wall is more polar. Polar compounds that have entered the bacterial cell immediately work to destroy bacteria by denaturing proteins that can cause metabolic activity. Bacterial cells stop because all the metabolic activities of bacterial cells are catalyzed by an enzyme which is a protein. The cessation of this metabolic activity will result in bacterial cell death [31].

In this study, it was found that the average number of S. aureus bacteria was less than the average number of E. coli bacteria, meaning that the antibacterial activity of the infusion of kaffir lime peel, manurun banana, and pineapple was better in inhibiting S. aureus than in inhibiting E. coli. The effectiveness of a natural extract in inhibiting bacterial growth is influenced by the composition and properties of the bacterial cell membrane. 45 Differences in the nature and characteristics of gram-positive and negative bacteria can affect the colonization and effectiveness of the work of antibacterial substances.

The main constituent of the cell wall of gram-positive bacteria, such as S. aureus is very thick peptidoglycan, with the largest composition being teichoic acid and various polysaccharides that have polar characteristics but are susceptible to lysozyme. Cell walls that have polar characteristics and are susceptible to these bactericidal substances, so that bactericidal compounds can easily damage the cell components of gram-positive bacteria [44] The composition of most gram-negative bacterial cell membranes is a lipopolysaccharide and phospholipid bilayer which tends to be nonpolar. This causes polar compounds to be difficult to penetrate the cell wall [31,45].

5. Conclusion

There were differences in the antibacterial activity of the infusion of the peels of kaffir limes, manurun bananas, and pineapples that are based on the number of S. aureus and E. coli bacteria colonies. 100% infusion of kaffir lime peel had the effect of reducing the number of tested bacterial colonies better than all tested infusion treatments (p < 0.05).

Further research can be done by using methanol or ethanol solvents as the ingredients of plant fruit peel extracts, so the extracts that can be obtained will have better effectiveness at concentrations below 100%. Similar research can also be developed using various types of other bacteria.

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