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PRESERVATION POTENTIAL AND MICROBIAL GROWTH INHIBITORY EFFECT OF GALANGAL (*Alpinia galanga* (L.) Willd.) AND LEMONGRASS (*Cymbopogon citratus* (DC.) Stapf) OILS AND EXTRACTS ON CHICKEN (*Gallus domesticus*) FILLETS

*Potensi Pengawetan dan Aktivitas Penghambatan Pertumbuhan Mikroba Minyak Atsiri dan Ekstrak Rimpang Lengkuas (Alpinia galanga (*L.*)* Willd.*) dan Daun Sereh (Cymbopogon citratus (*DC.*)* Stapf*) pada Daging Ayam (Gallus domesticus)*

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***ABSTRACT* / ABSTRAK**

Lengkuas (Alpinia galanga (L.) Willd.*) dan sereh (Cymbopogon citratus* (DC.) Stapf) *merupakan bumbu dapur dengan aktivitas antimikroba yang kuat dan berpotensi dikembangkan menjadi bahan pengawet makanan alami. Penelitian ini bertujuan untuk mengevaluasi potensi kedua bahan tersebut sebagai bahan pengawet makanan alami. Minyak atsiri dan ekstrak air rimpang lengkuas dan daun sereh masing-masing diperoleh melalui metode distilasi uap-air dan metode infusa. Fillet ayam direndam dalam tiga konsentrasi minyak atsiri dan ekstrak lengkuas dan sereh, dengan air steril sebagai kontrol. Fillet ditutup rapat, disimpan dalam lemari es selama 15 hari, dan dievaluasi potensi pengawetan daging ayam dan aktivitas penghambatan mikrobanya pada hari ke-3, 6, 9, 12, dan 15. Potensi pengawetan fillet ayam dievaluasi dengan membandingkan waktu mulai munculnya tanda-tanda pembusukan daging ayam pada kelompok kontrol dan kelompok perlakuan. Persentase penghambatan pertumbuhan mikroba (%PPM) dihitung dari kerapatan optik dan digunakan sebagai parameter aktivitas antimikroba. %PPM dianalisis dengan ANOVA dua arah pada α=0,05. Kemompok perlakuan dan lama penyimpanan mempengaruhi %PPM secara bermakna. Ekstrak lengkuas pada konsentrasi 10 dan 20% menunda munculnya bau tengik, tekstur lembek, dan lendir selama sembilan hari. Aktivitas penghambatan pertumbuhan mikroba ditunjukkan oleh minyak lengkuas pada konsentrasi 0,25; 1,25; dan 6,25 mg/ml dan ekstrak lengkuas pada 20%. Dengan demikian, ekstrak lengkuas 20% menunjukkan potensi yang paling baik dan bisa dikembangkan menjadi pengawet alami daging ayam.*

Galangal (*Alpinia galanga* (L.) Willd.) and lemongrass (*Cymbopogon citratus* (DC.) Stapf) are spices known for their antimicrobial activity and potentially developed into a natural food preservative. This study evaluated the potential development of galangal and lemongrass oils and extracts for natural food preservatives. The essential oils and water extracts of galangal and lemongrass were obtained by water and steam distillation and infusion methods, respectively. Chicken fillets were immersed in three concentrations of galangal and lemongrass oils and extracts, with sterile water as the control. The fillets were tightly closed, kept in the refrigerator for 15 days, and evaluated for their preservation potential and microbial inhibitory activity on days 3, 6, 9, 12, and 15. The chicken fillet preservation potential was evaluated by comparing the time spoilage signs started to be observable in the control and treatment groups. The percent of microbial growth inhibition (%MI) was calculated from optical density (OD) and was used as the antimicrobial activity parameter. The %MI was analyzed by two-way ANOVA at α=0.05. Treatment and storage time significantly affected %MI. Galangal extracts at 10 and 20% delayed rancid odor, off-texture, and slime formation for nine days. Microbial growth inhibitory activity was shown by galangal oil at 0.25, 1.25, and 6.25 mg/ml and galangal extract at 20%. In conclusion, galangal extract at 20% was the most promising sample potentially developed into a natural chicken fillet preservative.

INTRODUCTION

Chicken meat is one of the most popular proteins, with consumption per capita in Indonesia of 14.2 kg and a total consumption of 132.3 million tons worldwide in 2021 (Helgi Library, 2024; Statista, 2024). However, it is highly perishable due to microbial growth, enzymatic reaction, and oxidation (Luong et al., 2020). In addition, contamination of pathogenic bacteria, i.e., *Salmonella* sp., *Campylobacter* sp., *Staphylococcus aureus,* and *Escherichia coli*, is commonly reported (Gonçalves-Tenório et al., 2018). Without proper preservation, chicken meat spoils quickly, leading to foodborne illnesses.

Recently, there has been increasing attention toward natural preservatives sourced from spices. Not only for their antimicrobial properties, spice-derived preservatives are also valued for their high acceptability due to consumer familiarity with their sensory attributes. In addition, spices align with consumer preference for natural alternatives to synthetic ones (Sulieman et al., 2023). Galangal (*Alpinia galanga* (L.) Willd.) rhizomes and lemongrass (*Cymbopogon citratus* (DC.) Stapf) leaves have been long utilized as spices in chicken-based meals in Southeast Asia. Galangal rhizomes have a distinct spicy and citrusy flavor and contain phenolic compounds, i.e., gallic acid and cinnamic acid derivates, and essential oils, i.e., 1,8-cineole and geraniol, which are likely antimicrobial compounds. The antimicrobial activity of galangal rhizome has been proven against *Candida albicans, Klebsiella pneumoniae, Micrococcus luteus, Proteus mirabilis, Pseudomonas aeruginosa,* and *Streptococcus aureus* (Aljobair, 2022; Pillai et al., 2019; Zhou et al., 2021). On the other hand, the distinctive lemony-scent lemongrass contained high levels of citral with its profound antimicrobial properties. The efficacy of lemongrass as an antimicrobial has been proven against *Staphylococcus aureus* and *Candida albicans* (Boeira et al., 2020; Dangol et al., 2023).

The application of galangal and lemongrass in food preservation is not only defined by their antimicrobial activity but also by their advantage in maintaining the sensory qualities of the food. These spices enhance the overall sensory experience of preserved foods. Their flavors and aromas make the preserved products more appealing to consumers. Unlike synthetic preservatives, which may alter taste and odor, these natural ingredients maintain the authentic sensory qualities of the food (Gottardi et al., 2016). This study aims to investigate the preservation potential and microbial growth inhibitory effects of galangal and lemongrass essential oils and water extracts on chicken fillets. By evaluating these two parameters, we aim to provide insights into the feasibility of their application as natural chicken meat preservatives.

METHOD

Materials

The galangal rhizomes and lemongrass leaves were obtained from Bawang (Banjarnegara) and Kembaran (Banyumas). Plant identity was authenticated in the Laboratory of Plant Taxonomy, Jenderal Soedirman University, Purwokerto (ref no 139/2015 and 132/2015). Chicken fillets were purchased from a local East Purwokerto (Banyumas) market. Nutrient broth (NB) was from Oxoid (England).

Preparation of Water Extracts and Essential Oils

Galangal and lemongrass water extracts were prepared by infusion method in concentrations of 5,10, and 20%. The essential oils were obtained by water and steam distillation methods and were prepared into a mixture with water by vigorous stirring. Galangal oil was prepared into 0.25, 1.25, and 6.25 mg/ml concentrations, while lemongrass was 0.125, 0.625, and 3.125 mg/ml (Hamad et al., 2023, 2021, 2019).

Chicken Meat Treatment

The fresh chicken meat was cleaned, deskinned, filleted, and cut into cubes (1x1x1 cm). The cubes were briefly immersed in boiling water to reduce the microbial contamination on the surface and aseptically put in the Erlenmeyer flasks containing 100 ml of three concentrations of galangal and lemongrass water extracts, three concentrations of essential oil mixtures or sterile water as the control. The flasks are tightly closed and stored in the refrigerator at 4±2°C for 15 days. The fillet physical characteristics observation and the indirect bacterial enumeration were conducted on days 3, 6, 9, 12, and 15.

Evaluation of Preservation Potential

The fillets were subjected to evaluation of characters, i.e., for color, odor, texture, and formation of slime, which were compared to the fresh fillet of the same origin (Al-Baadani et al., 2023). The preservation potential was calculated by a formulation as follows:

$$Preservation\ potential = FC\ sample - FC\ control$$

FC represents the day when the first sign of spoilage is observable in each group.

Microbial Growth Inhibitory Activity Evaluation

Fillets were transferred into 10 ml of sterile water. 100 µl of the suspension was transferred and homogenously mixed in 10 ml of NB. The mixture was incubated for 24h at 37°C. The bacterial enumeration was conducted by optical density (OD) measurement of cultured suspensions with a UV-Vis spectrophotometer (Shimadzu, Japan) at 600 nm. The percentage of microbial growth inhibition (%MI) is calculated according to the formula (Mira et al., 2022) as follows:

$$\%MI = 100 \times \frac{(OD\ control - OD\ sample)}{OD\ sample}$$

Data Analyzes

The effect of different treatments and storage time on %MI and their comparison were analyzed by two-way ANOVA and Duncan's test. Significant effects and differences were assigned at $p<0.05$. Statistical analysis was conducted using IBM SPSS ver.26 (IBM Statistic, US).

RESULTS

Fresh fillets were pinkish white, firm, and had a distinctive odor of fresh chicken. Treatment with water extracts changed fillet color to brown, with the higher concentration resulting in a deeper shade of color, and galangal extracts generated darker-colored meat than lemongrasses. The fillet color went darker with the increasing time. Galangal oil did not change fillet color, but lemongrass one colored them into a yellowish hue at 0.625 mg/ml and higher concentrations (Table 1). Hence, we did not use fillet color as the chicken meat spoilage parameter.

Table 1. Physical Characteristics of Fillet During Storage

Treatment group	Characters	Preservation time (day)				
		3	6	9	12	15
Control	Color	Pinkish white	Pinkish white	Pinkish white	**Pale white**	**Pale white+**
	Odor	Fresh chicken	Fresh chicken	Fresh chicken	**Rancid**	**Rancid+**
	Texture	Firm	**Softer**	**Softer**	**Softer+**	**Softer++**
	Slime	-	-	+	++	++

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Galangal EO 0.25 mg/ml	Color	Pinkish white	Pinkish white	Pinkish white	Pinkish white	Pinkish white
	Odor	Aromatic galangal+	Aromatic galangal+	**Aromatic galangal**	**Aromatic galangal**	**Rancid**
	Texture	Firm	Firm	Firm	Firm	**Softer**
	Slime	-	-	-	+	++
Galangal EO 1.25 mg/ml	Color	Pinkish white	Pinkish white	Pinkish white	Pinkish white	Pinkish white
	Odor	Aromatic galangal++	Aromatic galangal++	**Aromatic galangal+**	**Aromatic galangal+**	**Aromatic galangal+**
	Texture	Firm	Firm	Firm	Firm	**Softer**
	Slime	-	-	-	-	+
Galangal EO 6.25 mg/ml	Color	Pinkish white	Pinkish white	Pinkish white	Pinkish white	Pinkish white
	Odor	Aromatic galangal+++	Aromatic galangal+++	**Aromatic galangal++**	**Aromatic galangal+**	**Aromatic galangal+**
	Texture	Firm	Firm	Firm	Firm	**Softer**
	Slime	-	-	-	-	+
Galangal WE 5%	Color	**Brown**	**Brown**	**Brown+**	**Brown+**	**Brown++**
	Odor	Aromatic galangal	Aromatic galangal	Aromatic galangal	Aromatic galangal	**Aromatic galangal, rancid**
	Texture	Firm	Firm	Firm	Firm	**Softer**
	Slime	-	-	-	-	-
Galangal WE 10%	Color	**Brown+**	**Brown+**	**Brown+**	**Brown++**	**Brown++**
	Odor	Aromatic galangal	Aromatic galangal	Aromatic galangal	Aromatic galangal	Aromatic galangal
	Texture	Firm	Firm	Firm	Firm	**Softer**
	Slime	-	-	-	-	-
Galangal WE 20%	Color	**Brown++**	**Brown++**	**Brown+++**	**Brown+++**	**Brown++++**
	Odor	Aromatic galangal	Aromatic galangal	Aromatic galangal	Aromatic galangal	Aromatic galangal
	Texture	Firm	Firm	Firm	Firm	**Softer**
	Slime	-	-	-	-	-
Lemongrass EO 0.125 mg/ml	Color	Pinkish white	Pinkish white	Pinkish white	Pinkish white	Pinkish white
	Odor	Aromatic lemongrass+	Aromatic lemongrass+	Aromatic lemongrass+	Aromatic lemongrass+	Aromatic lemongrass+
	Texture	Firm	Firm	Firm	**Softer**	**Softer**
	Slime	-	-	-	+	+
Lemongrass EO 0.625 mg/ml	Color	**Yellowish white**	**Yellowish white**	**Yellowish white**	**Yellowish white**	**Yellowish white**
	Odor	Aromatic lemongrass++	Aromatic lemongrass++	Aromatic lemongrass++	Aromatic lemongrass++	Aromatic lemongrass++
	Texture	Firm	Firm	Firm	**Softer**	**Softer**
	Slime	-	-	-	+	+
Lemongrass EO 3.125 mg/ml	Color	**Yellowish white**	**Yellowish white**	**Yellowish white**	**Yellowish white**	**Yellowish white**
	Odor	Aromatic lemongrass+++	Aromatic lemongrass+++	Aromatic lemongrass+++	Aromatic lemongrass+++	Aromatic lemongrass+++
	Texture	Firm	Firm	Firm	**Softer**	**Softer**
	Slime	-	-	-	+	+
Lemongrass WE 5%	Color	**Light brown**	**Light brown**	**Brown**	**Brown**	**Brown+**
	Odor	Aromatic lemongrass	Aromatic lemongrass	**Rancid**	**Rancid+**	**Rancid++**
	Texture	Firm	Firm	**Softer**	**Softer+**	**Softer++**
	Slime	-	-	-	+	+
Lemongrass WE 10%	Color	Brown	Brown	**Brown+**	**Brown+**	**Brown++**
	Odor	Aromatic lemongrass+	Aromatic lemongrass+	**Aromatic lemongrass**	**Rancid**	**Rancid+**

	Texture	Firm	Firm	**Softer**	**Softer+**	**Softer++**
	Slime	-	-	-	+	+
Lemongrass WE 20%	Color	Brown+	Brown+	**Brown++**	**Brown+++**	**Brown+++**
	Odor	Aromatic lemongrass++	Aromatic lemongrass++	**Aromatic lemongrass+**	**Aromatic lemongrass**	**Rancid**
	Texture	Firm	Firm	**Softer**	**Softer+**	**Softer++**
	Slime	-	-	-	+	+

EO = essential oil, WE = water extract, bold type indicates changes in particular character

The preservation potential was estimated from the first changes in color, odor, or texture. The longer time represented the better preservation potential. Galangal showed a better preservation potential than lemongrass. The best preservation potential regarding odor changes was shown by lemongrass oils (for nine days), while that of texture was galangal (9 days). On the other hand, the most extended delayed slime formation was shown by galangal extracts. Hence, the best overall preservation potential was observed in galangal water extracts at 10 and 20% for delaying all changes in odor and texture and slime formation for nine days (Fig. 1).

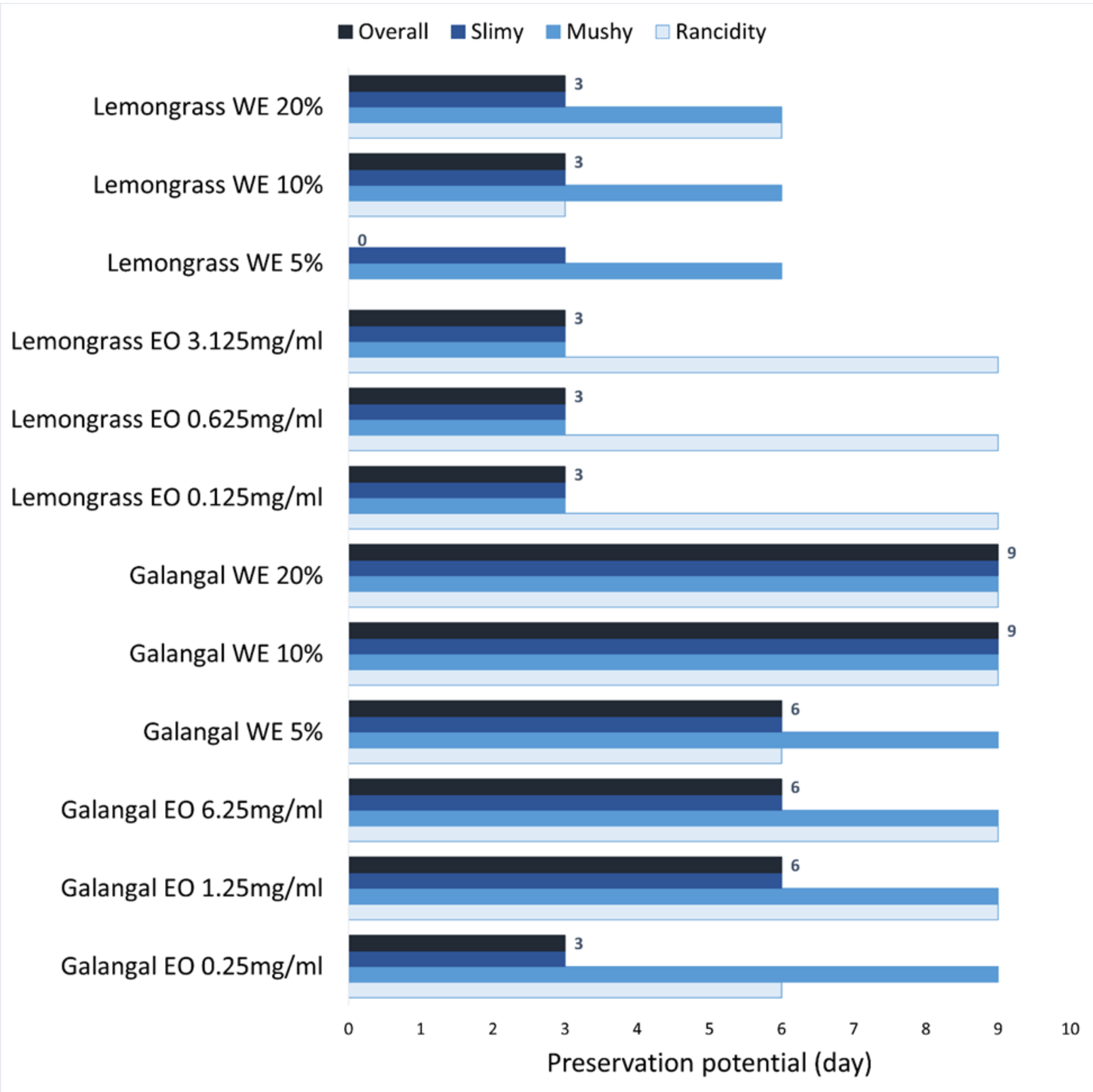

Fig. 1. Preservation Potential Profile of Galangal and Lemongrass Oils and Extracts of Chicken Fillets; EO = Essential Oil, WE = Water Extract

Treatment with galangal and lemongrass oils and extracts significantly affected the microbial growth on fillet (p=0.000). A positive %MI value represented microbial growth inhibition. Hence, only all three concentrations of galangal oil and galangal extract at 20% showed microbial growth inhibitory activity. The statistically best inhibition was demonstrated by galangal oil at 6.25 mg/ml and galangal extract at 20%. Storage time also statistically affected the microbial growth on fillets (p=0.000). The lowest inhibition occurred on days 6 and 9, with the highest on days 16. Hence, the microbial growth in the fillet followed the microbial growth curve, with the log phase at least until day 9 (Table 2).

Table 2. The Microbial Growth Inhibitory Activity of Galangal and Lemongrass Oils and Extracts

Treatment group	Percent of microbial growth inhibition (%)				
	Day 3	Day 6	Day 9	Day 12	Day 15
Galangal EO 0.25 mg/ml	17.52±8.38^{Eb}	19.02±9.21^{Ea}	12.14±2.22^{Ea}	19.77±3.37^{Ebc}	-0.78±8.14^{Ec}
Galangal EO 1.25 mg/ml	26.95±13.84^{Fb}	27.92±15.50^{Fa}	21.87±9.10^{Fa}	43.43±20.10^{Fbc}	-0.78±9.04^{Fc}
Galangal EO 6.25 mg/ml	33.38±17.54^{GHb}	38.16±22.74^{GHa}	37.56±20.20^{GHa}	48.50±23.60^{GHbc}	4.41±5.37^{GHc}
Galangal WE 5%	-14.05±11.52^{BCb}	-1.88±5.57^{BCa}	-77.29±61.02^{BCa}	42.58±21.63^{BCbc}	16.64±1.16^{BCc}
Galangal WE 10%	0.20±1.61^{BCDb}	-1.01±4.96^{BCDa}	-68.39±42.14^{BCDa}	31.80±14.00^{BCDbc}	17.05±1.45^{BCDc}
Galangal WE 20%	24.03±12.14^{Hb}	55.17±34.73^{Ha}	4.78±2.98^{Ha}	54.27±29.89^{Hbc}	41.88±19.01^{Hc}
Lemongrass EO 0.125 mg/ml	1.16±0.94^{Db}	12.62±5.46^{Da}	-5.01±9.91^{Da}	0.93±7.82^{Dbc}	9.85±3.64^{Dc}
Lemongrass EO 0.625 mg/ml	-5.22±4.74^{CDb}	5.17±0.59^{CDa}	4.56±3.14^{CDa}	-18.69±21.70^{CDbc}	7.58±5.25^{CDc}
Lemongrass EO 3.125 mg/ml	-18.26±12.27^{BCb}	-18.97±17.65^{BCa}	-6.20±10.75^{BCa}	-5.61±12.45^{BCbc}	3.79±7.93^{BCc}
Lemongrass WE 5%	-9.60±7.28^{ABb}	-16.25±15.73^{ABa}	-3.24±8.65^{ABa}	-2.04±9.86^{ABbc}	-37.10±36.84^{ABc}
Lemongrass WE 10%	-4.52±4.34^{Ab}	-107.50±80.26^{Aa}	-1.32±7.30^{Aa}	5.68±4.47^{Abc}	0.81±10.04^{Ac}
Lemongrass WE 20%	1.51±0.86^{Bb}	-60.83±46.67^{Ba}	-4.85±9.80^{Ba}	5.33±5.42^{Bbc}	1.61±9.47^{Bc}

The different superscripted uppercase alphabets within the same column and lower-case ones in the same rows represent statistically different percent inhibition of microbial growth. EO = Essential oil, WE = water extract.

DISCUSSION

Galangal extracts used in this study contained phenolic compounds, tannins, and terpenoids, while lemongrass ones contained saponins, tannins, and terpenoids. The same extracts also changed the color of the treated tofu to brown (Hamad et al., 2021, 2019). Tannins are plant metabolites with a yellow to reddish-brown color responsible for the deep hue of matured fruits and foliage. These compounds interact with proteins and, under certain conditions, modify the color of the food matrix (Watrelot and Norton, 2020). The interaction between tannins and meat proteins is likely responsible for the deeper brown observed in fillets treated with higher extract concentrations for longer times. On the other hand, lemongrass oil used in this study mainly consisted of neral, geranial, and myrcene (Hamad et al., 2019). Neral and geranial are geometric isomers collectively called citral. They have a pale yellow color, which likely interacted with chicken meat and made it yellowish-white (Idrees et al., 2019).

Treatment with galangal and lemongrass water extracts and essential oils modified the fillet odor with their aromatic scent. The odor intensity was stronger in those treated with essential oils and gradually weaker with time. However, we did not use changes in the aromatic odor as the meat spoilage parameter and used the rancid, foul odor as one. The rancid odor in fillets in the control group was observed on day 9. Those treated with the lowest concentrations of galangal water extract and essential oil started to show a rancid odor on day 15. In contrast, those treated in higher concentrations did not show any changes until the final day of treatment. Rancidity was not observed in fillets treated with lemongrass oils and started to be present in those treated with lower, medium, and higher concentrations of lemongrass extracts on days 9, 12, and 15, respectively.

Citral has a strong, lemony, aromatic scent (Idrees et al., 2019). However, the aromatic scent of lemongrass oils inhibited the rancid odor of the spoiled meats rather than just masking it. They inhibited odor-causing microbial growth, so the spoilage was delayed, and the rancidity occurred later. Hence, the occurrence of rancidity of fillets is directly correlated to the antimicrobial activity of the samples. The effectiveness of lemongrass essential oils in delaying off-odor on the fillets might be attributable to the citral content, which has been proven to have potential antimicrobial effects.

Fillet texture was utilized as a parameter of meat spoilage. Fillets in the control group started to be softer on day 6. Fillets treated with all galangal extract and oil concentrations started to be mushy on day 15. Softness was observed in those treated with lemongrass oil and extract on days 9 and 12, respectively. Protein denaturation, lipid degradation, enzymatic reactions, and chemical property changes played a role in meat texture changes during storage (Zhang et al., 2023). Among those factors, lipid degradation and enzymatic reactions might be linked to microbial metabolism. Microorganisms produce enzymes that break down proteins and lipids, eventually affecting meat's texture. Hence, the undesirable changes in fillet texture are also a sign of microbial spoilage on food. Slime formation was also a parameter for meat spoilage in this study. Slimy fillets in the control group were noticeable on day 9, while they started to present in those treated with galangal oils on day 12. Slime formation in fillets treated with the lowest concentration of galangal extracts was noticeable on day 15, and it was not observable in the higher concentrations until the final day of observation. On the other hand, fillets treated with lemongrass oils and extracts started to be slimy on day 12 (Table 1). Microbial activity can also cause slime to form on meat during storage. *Pseudomonas* sp. contamination particularly generates a putrid odor and slime on the surface of meat (Luong et al., 2020).

Previous studies reported the preservation potential of various forms of galangal rhizome on beef, milkfish, tilapia, and tofu. Galangal water extract at 20% maintained the tofu’s odor and texture taste for two days longer than the control. At 40%, it preserved tilapia fish for three days at room temperature (Apriyanti et al., 2021; Hamad et al., 2021). Galangal juice prolonged the shelf life of milkfish up to 46 hours, while beef treated with 30% galangal paste for four days showed the most favorable organoleptic and chemical characteristics, cooking loss, and microbial count (Inayah and Bestari, 2018; Toba et al., 2018). Galangal oil at 0.25 mg/ml showed preservation potential for four days under room temperature storage (Hamad et al., 2023). Similarly, the preservation potential of lemongrass has been evaluated for bakery products, such as chicken sausage, orange juice, tofu, and vegetables. Lemongrass water extract at 20% and essential oil at 0.125 mg/ml prolonged tofu shelf life at room temperature for four days (Hamad et al., 2019).

Lemongrass essential oil at 1.25 µl/ml demonstrated antimicrobial and antioxidant activities that significantly improved the orange juice's natural and microbiological properties at 4 °C-storage. It can also be applied to the packaging of bakery products and vegetables to protect them from microbial contamination (Abou-Raya et al., 2023; Valková et al., 2022). Lemongrass extract could keep the quality of chicken sausage for up to 42 days under refrigerated storage (Boeira et al., 2020).

%MI directly represented the antimicrobial activity of the tested samples. The solid antimicrobial effects of galangal extracts might be linked with its phenolic compound content, which has been proven to inhibit or kill microorganisms through the mechanisms of interference with the synthesis of cell walls, proteins, and nucleic acids, modifying essential metabolic pathways, and disturbance of cell membrane function (Ecevit et al., 2022). The non-flavonoid phenolic compounds in the galangal rhizome included gallic acid, catechin, cinnamic acid, and protocatechuic acid (Aljobair, 2022). Gallic acid showed antimicrobial effects against *Escherichia coli*, *Listeria* sp., and *Salmonella* sp., which was by mechanisms of altering cell membrane structure, disrupting metabolism, and inhibiting biofilm formation (Flores-Maldonado et al., 2024). Similarly, cinnamic acid and its derivatives have also been proven to have antimicrobial properties (Guzman, 2014).

The oxygenated compounds, particularly phenols, aldehydes, and ethers, among volatile oil constituents, showed the most substantial antimicrobial effects (Li et al., 2014). The galangal oil used in this study contained mainly 1,8-cineole, 4-allylphenyl acetate, geranyl acetate, α-pinene, and β-farnesene, with 69% of oxygenated compounds (Hamad et al., 2023). Hence, the high %MI of galangal oil might be attributable to the oxygenated compound contents. 1,8-cineol demonstrated antimicrobial activity against methicillin-resistant *Staphylococcus aureus* through mechanisms of damaging cell membrane integrity and inducing reactive oxygen species-mediated oxidative stress (Merghni et al., 2023). Nevertheless, this result is similar to our previous report that galangal oil showed better inhibition of microbial growth on tofu (Hamad et al., 2022).

Combining the results of preservation potential and microbial inhibition activity, the most prominent effect was shown by galangal extract at 20%. However, using such a high concentration of galangal rhizomes changed the fillet color into dark brown, which might be undesirable for consumption by most populations. Sensory and hedonic analyses should be conducted to evaluate whether the changes are acceptable.

CONCLUSION

Galangal extract at 20% was the most promising candidate for natural chicken fillet preservative for delaying rancid odor, off-texture, and slime formation for nine days and significantly exhibited microbial growth inhibitory activity.

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