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Chemical Components of Essential Oils from Woods of *Cinnamomum burmanii* (Ness) BL, *Santalum album* Linn., and *Cryptocarya massoia* (Oken) Kosterm and Their Application as Antibacterial Additives in Transparent Herbal Soaps

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ABSTRACT

This study aimed to isolate and identify the chemical components of essential oils from woods of cinnamon (*Cinnamomum burmanii* (Ness) BL), sandalwood (*Santalum album* Linn.), and massoia (*Cryptocarya massoia* (Oken) Kosterm) and to determine their effect as additives for transparent herbal soap in terms of their antibacterial activity against *Staphylococcus aureus* ATTC 25923 and the soap quality. The results showed that cinnamon, sandalwood, and massoia essential oils contained, respectively, 14, 20, and 9 chemical components, all of which had been identified. The chemical components with the highest percentage contained in the essential oils of cinnamon, sandalwood, and massoia were cinnamaldehyde (91.71%), β-bisabolen (37.79%), and massoia lactone (77.56%), respectively. The soaps' antibacterial activity against *S. aureus* ATTC 25923 increased from moderate (with an inhibitory power of 9.67 mm) to strong. The addition of 3% massoia essential oil got the highest inhibitory power of 16.47 mm (strong), followed by that of 3% cinnamon essential oil and 3% sandalwood essential oil, getting 15.37 mm and 12.19 mm, respectively, both of which were considered strong as well. The results of the organoleptic description test showed that each soap had a distinctive color and aroma depending on the type of essential oil added. The quality test results, including transparency, pH, foam stability, water content, and saponification number, indicated that the formulation had good quality.

1. Introduction

A lot of plants native to Indonesia can produce natural compounds, which, however, have not been utilized as commercial products, such as essential oils. Cinnamon, sandalwood, and massoia are usually used for spices, incense for worship, and traditional medicine (Arumningtyas 2016; Rena 2017). Cinnamon, especially its bark, is widely used as a spice and an additive in food and beverages. It contains active compounds, including alkaloids, saponins, flavonoids, tannins, polyphenols, and essential oils (Mursyida and Wati 2021). It can be an antifungal, antiparasitic, antiviral, and antiseptic agent (Repi *et al*. 2016; Nisa *et al.* 2021). Sandalwood is widely used as a perfume and a means of worship. It has various chemical constituents. Its essential oil contains more than 90% sesquiterpenes; its main component is santalol. Sandalwood essential oil can be an antibacterial,

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anticancer, especially skin cancer, and antiviral agent (Agusta and Jamal 2001; Ariyanti and Asbur 2018). Massoia is widely used as a spice and an additional ingredient in food and beverages; the part used is its bark. It contains essential oils, flavonoids, tannins, steroids, terpenoids, and coumarins. The community has used it as a traditional medicine, such as herbal medicine, anthelmintic, and spice. Massoia can be an antibacterial and antioxidant agent (Sari *et al*. 2014).

To this day, essential oils derived from these three types of woods have not contributed much to the economic development of the community. Several steps must be taken to develop the production of forest products. In the context of innovation and commercialization of forest products to have commercial value, researchers have tried to develop transparent herbal soaps with the addition of essential oils from the three types of woods.

In the midst of the widespread use of chemical-based soaps, it is necessary to innovate herbal soap products that contain natural bioactive compounds. Transparent herbal soap is a type of transparent solid bath soap made from herbs. The advantages of transparent herbal soaps, compared to solid chemical-based bath soaps, are that they look more shiny, aesthetically pleasing, and clear, produce finer foam, and are safer for the skin (Widyasanti *et al.* 2017). Skin hygiene needs to be considered because many diseases are caused by bacteria, like *S. aureus* ATTC 25923, which are often found on the surface of the skin and are pathogenic. Antibacterial soaps circulating in the community contain a synthetic ingredient tryclosan, as an antimicrobial. Excessive use of tryclosan can interfere with growth hormones, kill normal skin flora, and cause bacteria to be resistant and undergo cell mutations (Gusviputri *et al*. 2013). This study aimed to isolate and identify the chemical components of essential oils of cinnamon, sandalwood, and massoia, and to determine their effect as additives for transparent herbal soaps in terms of their activity as an antibacterial agent against *S. aureus* ATTC 25923 and the quality of the soaps produced.

2. Materials and Methods

2.1. Materials

The materials used in this study included samples of cinnamon, sandalwood, massoia, anhydrous Na_2SO_4, olive oil, coconut oil, palm oil, NaOH, distilled water, glycerin, sucrose, alcohol 96%, KOH, MHA agar media, bacteria *Staphylococcus aureus* ATTC 25923, and vancomycin.

2.2. Sample Preparation and Plant Determination

The cinnamon, sandalwood, and massoia used as the research samples came from several regions in Indonesia. Cinnamon was obtained from Ternate, Maluku, Indonesia (1° North Latitude and 127° East Longitude); sandalwood was obtained from Kupang, Nusa Tenggara Barat, Indonesia (10° South Latitude and 123° East Longitude); massoia was obtained from Fakfak, Papua Barat, Indonesia (2° South Latitude and 133° East Longitude). The determination of cinnamon, sandalwood, and massoia was carried out at the Department of Biology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, Surakarta.

2.3. Sample Preparation

The cinnamon, sandalwood, and massoia samples used in this study came from plants that were approximately 20 years old, 15 meters tall, 20 cm in stem diameter, and brown. The three samples, separately, are sorted, washed, and chopped, then dried out of direct sunlight. The dried samples were stored in closed containers and ready to be isolated for their essential oils.

2.4. Essential Oil Extraction

In this study, the extraction of the essential oils from the samples was carried out using the water-steam distillation method. The bark of cinnamon, sandalwood, and massoia were isolated to extract their essential oils using the water-steam distillation method. The distillation apparatus has a capacity of 2.5 kg dry weight with a water capacity of 10 liters. The total of each sample is 10 kg, so it requires 4 times the distillation process. One process requires 12 cycles with a total time of 8 hours, so for 4 times, the distillation process takes a total time of 32 hours. The distillation process was then carried out and condensation was done to collect essentials. The distillation process was stopped when the liquid stopped dripping into the distillate flask. The fraction of essential oils was separated by a separating funnel. The top layer, which contains essential oil, was added with anhydrous Na_2SO_4 and filtered off (Ariani *et al.* 2022; Ariani *et al*. 2023). The isolated essential oils were then measured for their volumes, observed for their colors and aromas, and measured for their contents.

2.5. Identification of Chemical Components of Essential Oils Using the GC-MS Method

The essential oil of each plant was tested using the GC-MS method with the following equipment specifications: Rtx-5MS capillary column, with a column length of 30 m, a column diameter of 0.25 mm, an injector temperature of 200^{0}C, and a carrier gas He with a flow rate of 0.75 ml/min. The column temperature was programmed with an initial temperature of 60^{0}C and then slowly increased at a rate of 10^{0}C/minute until it reached a temperature of 200^{0}C.

2.6. Transparent Herbal Soap (THS) Formulation

Making Transparent Herbal Soap (THS) begins by heating a mixture of coconut oil, palm oil, and olive oil in a beaker on an electric stove at a temperature of around 70^{0}C and adding stearic acid and myristic acid until homogeneous, then adding 30% NaOH. After thickening, sucrose solution, NaCl, and lexaine are added. Finally, after the temperature is lowered to 40^{0}C, essential oils are added. The transparent herbal soap formulation can be seen in Table 1.

2.7. Test of the Antibacterial Activities of Essential Oils and Transparent Herbal Soap

Antibacterial activity tests were carried out on essential oils of cinnamon, sandalwood, massoia, and all soap formulations using the Paper Disc Diffusion method against *Staphylococcus aureus* ATTC 25923. In this test, vancomycin and distilled water were used as positive and negative controls, respectively. The diameters of the inhibition zones were measured using a vernier caliper around the disc blank and expressed in millimeters (Chastelyna *et al.* 2017).

2.8. Organoleptic Description Test

The organoleptic description test of the soaps was carried out visually through observations related to the soaps' colors and aromas (Supriyanta *et al*. 2021).

2.9. Transparent Herbal Soap Quality Test

The soap quality parameters tested included transparency, pH, foam stability, water content, and saponification number. Each test was carried out three times. The transparency test was carried out by reading 14 point fonts through each soap with a thickness of 0.25 inches (Supriyanta *et al*. 2021). The pH test was done using a pH meter (Supriyanta *et al*. 2021). The foam stability measurement was done by measuring the height of the initial and final foams. The water content test was carried out using the Gravimetric method (Sawiji *et al*. 2021). The saponification number test was carried out using the Titration method (Sawiji *et al*. 2021).

3. Results

3.1. Plant Determination

The plant determination carried out at the Department of Biology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret Surakarta showed that the samples to be used in the study were indeed *Cinnamomum burmanii* (Ness) BL (registration number 040/UN27.9.6.4/Lab/2022), *Santalum album* Linn. (registration number 062/UN27.9.6.4/Lab/2022), and *Cryptocarya massoy* (Oken) Kosterm (registration number 149/UN27.9.6.4/Lab/2022).

Table 1. Soap formulation

Composition	Satuan	F1	F2	F3	F4	F5	F6	F7	F8
Coconut oil	ml	21.0	21.0	21.0	21.0	21.0	21.0	21.0	
Olive oil	ml	7.0	7.0	7.0	7.0	7.0	7.0	7.0	
Palm oil	ml	7.0	7.0	7.0	7.0	7.0	7.0	7.0	U
NaOH	g	27.0	27.0	27.0	27.0	27.0	27.0	27.0	N
Distilled water	ml	16.0	16.0	16.0	16.0	16.0	16.0	16.0	K
Alcohol 96%	ml	15.0	15.0	15.0	15.0	15.0	15.0	15.0	N
Glycerin	ml	10.0	10.0	10.0	10.0	10.0	10.0	10.0	O
Sucrose	g	13.5	13.5	13.5	13.5	13.5	13.5	13.5	W
Cinnamon essential oil	%	0.0	1.0	3.0	0.0	0.0	0.0	0.0	N
Sandalwood essential oil	%	0.0	0.0	0.0	1.0	3.0	0.0	0.0	
Massoia essential oil	%	00	0.0	00	0.0	0.0	1.0	3.0	

F1: THS + 0% Essential oil (EO), F2: THS + 1% Cinnamon EO, F3: THS + 3% Cinnamon EO, F4: THS + 1% Sandalwood EO, F5: THS + 3% Sandalwood EO, F6: THS + 1% Massoia EO, F7: THS + 3% Massoia EO, F8: Control transparent herbal soap

3.2. Essential Oil Isolation

The results of the isolation of the essential oil of each sample can be seen in Table 2.

3.3. Identification of Chemical Components of Essential Oils with the GC-MS Method

3.3.1. Identification of Cinnamon Essential Oil

The results of the analysis using GC-MS methods, as presented in Figure 1, show that cinnamon essential oil has 14 compounds. The identified chemical components of cinnamon essential oil are presented in Table 3. Cinnamaldehyde was the main component of cinnamon essential oil, with a percentage of 91.71%, and was classified as an aldehyde compound.

3.3.2. Identification of Sandalwood Essential Oil

The results of the analysis using GC-MS methods, as presented in Figure 2, showed that sandalwood essential oil has 20 compounds. The identified chemical components of sandalwood essential oil are presented in Table 4.

Table 2. Essential oil isolation results

Essential oil	Color	Aroma	Sample mass (kg)	Volume (ml)	Content ($\frac{v}{m}$%)
Cinnamon	Clear yellow	Cinnamon	10	63	0.63
Sandalwood	Clear yellow	Sandalwood	10	136	1.36
Massoia	Brownish	Massoia	10	142	1.42

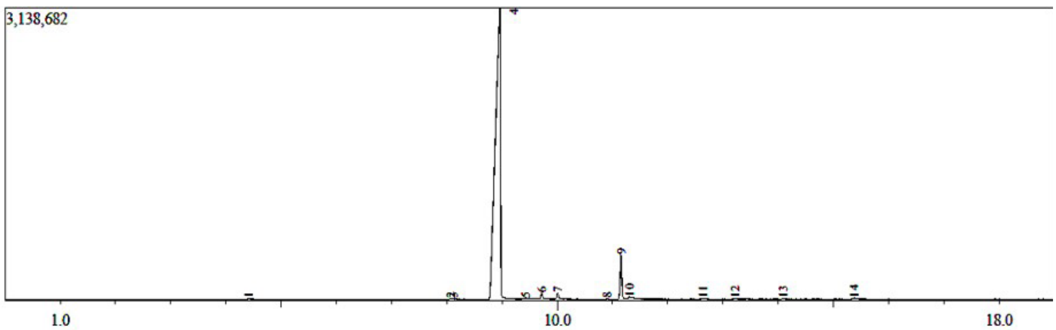

Figure 1. Chromatogram of the chemical components of cinnamon essential oil

Table 3. Results of identification of chemical components of cinnamon essential oil

Retention time (minute)	Retention index (RI)	Molecular weight	% area	Compound name
4.412	960	106	0.16	Benzaldehyde
8.072	1273	132	0.19	3-Phenyl-2-Propenal
8.116	1274	336	0.12	1H-Imidazole-2-methanol,α –heptadecyl
8963	1275	132	91.71	Cinnamaldehyde
9.422	1309	134	0.35	Cinnamyl alcohol
9.718	1339	218	0.56	Triacetin
10.005	1365	164	0.68	Eugenol
10.889	1416	204	0.08	trans-Caryophyllene
11.156	1439	176	4.83	Cinnamyl Acetate
11.305	1441	146	0.65	Coumarins
12.637	1599	222	0.21	4-Methyl-Oxetan-2-One
13.218	1602	222	0.11	Guaiol
14.091	1650	222	0.15	Elemol
15.369	1760	212	0.20	Benzyl Benzoate
Chemical component group				
Aldehydes (No. 1, 2, 4)				92.06%
Alcohols (No. 3, 5, 13)				0.62%
Esthers (No. 9, 14)				5.03%
Ketones (No. 11)				0.21%
Triglycerides (No. 6)				0.56%
Phenyl Propanoids (No. 7, 10)				1.33%
Sesquiterpenes (No. 8, 12)				0.19%
Total identified chemical components				100.00%

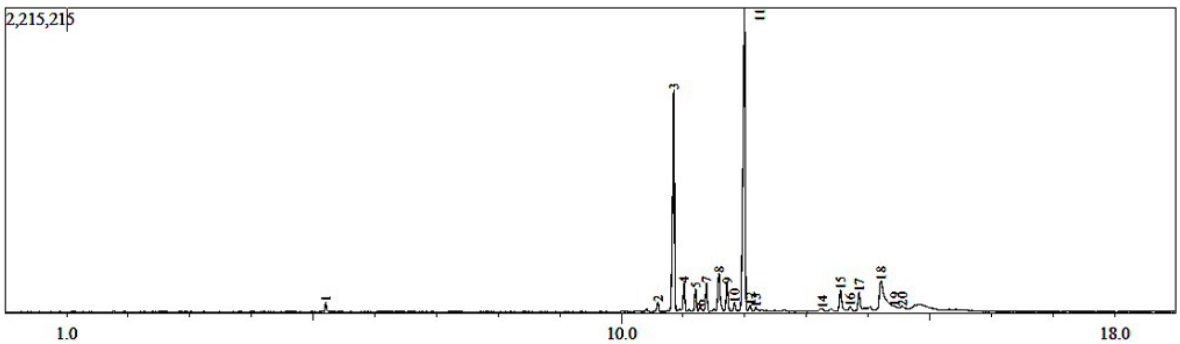

Figure 2. Chromatogram of the chemical components of sandalwood essential oil

Table 4. Results of identification of chemical components of sandalwood essential oil

Retention time (minute)	Retention index (RI)	Molecular weight	% area	Compound name
5.205	1027	136	0.77	Limonene
10.591	1411	278	1.00	(2,6,6-Trimethyl-Cyclohex-1-Enylmethanesulfonyl)-Benzene
10.849	1428	204	24.54	Santalene
11.017	1430	204	2.83	α-Bergamotene
11.203	1431	204	2.27	β-Farnesene
11.278	1434	236	0.68	6-(2,6,6-Trimethyl-1-Cyclohexenyl)-4-Metill-(E)-3-Hexenol
11.378	1437	204	3.02	β- Santalene
11.583	1444	204	5.24	trans-Caryophyllene
11.714	1445	204	3.04	γ-Elemene
11.834	1447	204	0.94	α-Santalene
11.996	1505	204	37.79	β-Bisabolene
12.089	1509	204	0.67	Farnesene
12.178	1525	204	0.53	β-Sesquiphellandrene
13.257	1548	222	0.60	Epiglobulol
13.553	1562	220	3.01	Salvial-4(14)-en-1-one
13.707	1573	204	0.79	Cis-Caryophyllene
13.855	1581	220	2.00	(-)-Caryophyllene oxide
14.208	1671	220	9.19	α-Santalol
14.435	1710	190	0.57	Sin-Tricyclo[5.1.0.0e2,4]Oct-5-En, 3,3,5,6,8,8-Hexamethyl-
14.556	1744	220	0.52	Santalol
Compound component group				
Alcohols (No. 6, 14, 18, 20)				10.99%
Ketones (No. 15)				3.01%
Monoterpenes (No. 1, 13)				1.30%
Sesquiterpenes (No. 3, 4, 5, 7, 8, 9, 10, 11, 12, 16, 17)				83.13%
Hydrocarbons (No. 2, 19)				1.57%
Total identified chemical components				100.00%

The largest component of sandalwood essential oil was β-Bisabolene, with a percentage of 37.79%, and belonged to the sesquiterpene group.

3.3.3. Identification of Massoia Essential Oil

The results of the analysis using GC-MS methods, as presented in Figure 3, showed that massoia essential oil has 9 compounds. The identified chemical components of massoia essential oil are presented in Table 5. Massoia lactone was the main component of Massoia essential oil, with a percentage of 77.56%, and it belonged to the ketone group.

3.4. Test of Antibacterial Activity of Transparent Herbal Soap and Essential Oils

3.4.1. Antibacterial Activity of Essential Oils

Based on the three essential oil samples, all have good antibacterial activity ability against *Staphylococcus aureus* ATCC 25923 bacteria. Cinnamon essential oil has the highest antibacterial ability and is in the very strong

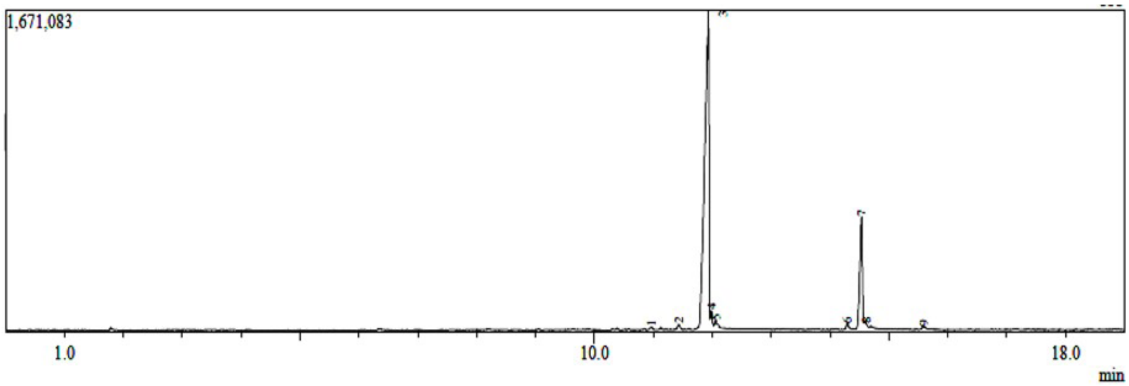

Figure 3. Chromatogram of the chemical components of massoia essential oil

Table 5. Results of identification of chemical components of massoia essential oil

Retention time (minute)	Retention index (RI)	Molecular weight	% area	Compound name
10.959	1419	204	0.36	delta-Guaiene
11.431	1450	152	0.72	Isogeraniol
11.932	1501	168	77.56	Massoia lactone
11.985	1503	124	1.68	2,3-Nonadiene
12.058	1505	170	1.33	delta-Decalactone
14.290	1513	138	0.68	1,6-Octadiene, 2,6-dimethyl
14.533	1520	168	16.46	2H-Piran-2-one, 5,6-dihydro-6-pentyl
14.605	1680	124	0.61	delta-Cyclogeraniolen
15.585	1760	212	0.60	Benzyl benzoate
Chemical component group				
Alcohol (No 2)				0.72%
Ketones (Nos 3, 5, 7)				95.35%
Esther (No 9)				0.60%
Sesquiterpene (No 1)				0.36%
Hydrocarbons (Nos 4, 6, 8)				2.97%
Total identified chemical components				100.00%

category. The results of the antibacterial activity test of essential oils against *S.aureus* ATCC 259233 based on the diameter of the inhibition zone for each sample are presented in Table 6.

3.4.2. Antibacterial Activity of Transparent Herbal Soaps

Based on the overall antibacterial activity test results of transparent herbal soap formulations, the highest antibacterial activity of transparent solid bath soap formulations can be seen based on the largest inhibition zone diameter of transparent herbal soap with 3% massoi wood essential oil addition (F7) with an average inhibition zone diameter of 16.47 mm and a strong category. The results of the antibacterial activity test of transparent herbal soaps against *Staphylococcus aureus* ATCC 259233 based on inhibitory power can be seen in Table 7.

3.5. Quality Evaluation of Transparent Herbal Soap

3.5.1. Transparency Test

The results of the transparency test of transparent herbal soaps showed (Figure 4) that all soap formulations could be said to be transparent because the 14 point fonts could be read through each soap with a thickness of 0.25 inches (Supriyanta *et al*. 2021).

3.5.2. pH test

The degree of acidity (pH) test results of all transparent herbal soaps have a pH value of 9. The pH test results showed that all soap formulations in Table 8.

Table 6. Results of test of antibacterial activity of essential oils

Sample	Average inhibition zone diameter (mm)	Standard Deviation	Category
EO1	46.28	0.03	Very strong
EO2	17.22	0.02	Strong
EO3	18.45	0.03	Strong
C +	13.57	0.02	Strong
C -	0.00	0.00	Weak

EO1: Cinnamon essential oil, EO2: Sandalwood essential oil, EO3: Massoia essential oil, C+: Positive control, C-: Negative control

Table 7. Results of test of antibacterial activity of essential oils

Sample	Average inhibition zone diameter (mm)	Standard deviation	Category
F1	9.67[a]	0.03	Moderate
F2	13.98[e]	0.03	Strong
F3	15.37[f]	0.02	Strong
F4	10.81[b]	0.03	Strong
F5	12.19[d]	0.02	Strong
F6	12.05[c]	0.02	Strong
F7	16.47[h]	0.02	Strong
F8	15.57[g]	0.03	Strong
C +	13.57	0.02	Strong
C -	0.00	0.00	Weak

F1: Transparent herbal soap (THS), F2: THS + 1% Cinnamon EO F3: THS + 3% Cinnamon EO, F4: THS + 1% Sandalwood EO F5: THS + 3% Sandalwood EO, F6: THS + 1% Massoia EO, F7: THS + 3% Massoia EO, F8: Control transparent herbal soap, C+: Positive Control, C-: Negative Control

Table 8. Transparent herbal soap pH test results

Sample	Average pH	Standard Deviation
F1	9[a]	0.00
F2	9[a]	0.00
F3	9[a]	0.00
F4	9[a]	0.00
F5	9[a]	0.00
F6	9[a]	0.00
F7	9[a]	0.00
F8	9[a]	0.00

F1: Transparent herbal soap (THS), F2: THS + 1% Cinnamon EO, F3: THS + 3% Cinnamon EO, F4: THS + 1% Sandalwood EO, F5: THS + 3% Sandalwood EO, F6: THS + 1% Massoia EO, F7: THS + 3% Massoia EO, F8: Control transparent herbal soap

Table 9. Transparent herbal foam stability test results

Sample	Average pH	Standard Deviation
F1	70.00[b]	0.02
F2	67.70[ab]	0.04
F3	63.56[ab]	0.03
F4	66.67[ab]	0.03
F5	61.33[a]	0.02
F6	68.37[ab]	0.03
F7	66.22 [ab]	0.02
F8	66.89[ab]	0.03

F1: Transparent herbal soap (THS), F2: THS + 1% Cinnamon EO, F3: THS + 3% Cinnamon EO, F4: THS + 1% Sandalwood EO, F5: THS + 3% Sandalwood EO, F6: THS + 1% Massoia EO, F7: THS + 3% Massoia EO, F8: Control transparent herbal soap

F1 F2 F3 F4

F5 F6 F7 F8

Figure 4. The result of the transparency test

3.5.3. Stability Test

A soap is said to have good foam stability if it has a foam stability value range of 60-70% after being left for 5 minutes (DeRagon *et al*. 1968). The graph of the stability test results of the resulting transparent herbal soaps' foams can be seen in Table 9.

3.5.4. Water Content Test

A soap's water content can affect its usability and hardness. The results of the water content test for the transparent herbal soaps can be seen in Table 10.

Table 10. Transparent herbal soap water content test

Sample	Average pH	Standard Deviation
F1	13.22[c]	0.03
F2	13.17[b]	0.02
F3	13.06[a]	0.02
F4	13.15[b]	0.01
F5	13.02[a]	0.03
F6	13.16[b]	0.01
F7	13.06[a]	0.02
F8	14.17[d]	0.03

F1: Transparent herbal soap (THS), F2: THS + 1% Cinnamon EO, F3: THS + 3% Cinnamon EO, F4: THS + 1% Sandalwood EO, F5: THS + 3% Sandalwood EO, F6: THS + 1% Massoia EO, F7: THS + 3% Massoia EO, F8: Control transparent herbal soap

Table 11. Transparent herbal soap saponification number test

Sample	Average pH	Standard Deviation
F1	204.31[f]	0.02
F2	203.15[a]	0.03
F3	197.44[e]	0.02
F4	202.84[c]	0.03
F5	199.73[d]	0.03
F6	203.49[b]	0.02
F7	198.94[g]	0.02
F8	205.42[h]	0.04

F1: Transparent herbal soap (THS), F2: THS + 1% Cinnamon EO, F3: THS + 3% Cinnamon EO, F4: THS + 1% Sandalwood EO, F5: THS + 3% Sandalwood EO, F6: THS + 1% Massoia EO, F7: THS + 3% Massoia EO, F8: Control transparent herbal soap

3.5.5. Saponification Number Test

The saponification number is the amount of alkali required to saponify a certain amount of oil. The higher the saponification number, the higher the free fatty acid content in the oil, so more alkali is needed to saponify the oil (Sukeksi *et al*. 2017). Based on the results of the saponification number test, the soap with the highest saponification number value is the comparison soap (F8), which is 205.42 mg/g. The result of the saponification number test results for the resulting transparent herbal soap can be seen in Table 11.

4. Discussion

The chemical components of cinnamon essential oil in this study were dominated by aldehyde groups consisting of 3 compounds (92.06%), the primary of which was cinnamaldehyde (91.71%). In this study, essential oil derived from the stem bark of 12-year-old *C. burmannii* plants had a main content of cinnamaldehyde of 91.71%. This content was greater when compared to the results of research by Fajar *et al*. (2019), which states that the essential oil of the stem bark of *C. burmannii* aged 20, 12 and 5 years had a cinnamaldehyde content of 75.97%, 81.61% and 79.25%, respectively. This is in accordance with existing research where essential oil from cinnamon has the largest cinnamaldehyde content, which is around 65%-80% (Liaqat *et al*. 2023). Based on SNI 06-3734-2006, cinnamaldehyde should be at least 50% of cinnamon essential oil. Thus, the cinnamon essential oil in this study complies with the established quality standards. The study of Pratiwi *et al.* (2015) showed that GC-MS analysis showed that cinnamaldehyde (92.02%) was the main constituent of the essential oil from cinnamon bark from Yogyakarta, Indonesia.

The chemical components of sandalwood essential oil were dominated by the sesquiterpene group consisting of 11 compounds (83.13%). Based on this study, the highest component in sandalwood essential oil belongs to the sesquiterpene group. The research by Subasinghe *et al*. (2013) stated that the essential oils from 2 sandalwood trees originating from Sri Lanka contained the main chemical component santalol, with concentrations of 56.38% and 47.73%, respectively.

Massoia lactone was the main component of massoia essential oil in this study (77.56%). Based on SNI 8285:2016, massoia essential oil should contain massoi lactone (≥70%). Therefore, the results of this study were in accordance with the established quality standards. This is in accordance with existing research where essential oil from massoia produces a fraction with massoia lactone as a major content (Batubara *et al*. 2019). The research of Pratiwi *et al.* (2015) showed that massoia lactone (92.05%) was the main constituent of the essential oil from massoia bark from West Papua, Indonesia.

Cinnamon essential oil (46.28 ± 0.03 mm) had the strongest antibacterial activity against *S. aureus* ATCC 25923. It was categorized as very strong, while sandalwood (17.22 ± 0.02 mm) and massoia (18.45 ± 0.03 mm) essential oils were categorized as strong (Table 5). Differences in the diameter of the inhibition zones could be caused by differences in the sensitivity of each bacteria to antibacterial or antimicrobial substances for their different cell structures and components and the chemical components contained in each essential oil (Ahamed *et al*. 2016). Research by Hakim *et al*. (2020) showed that concentrations of 2%, 4%, and 8% essential oil from cinnamon bark (*Cinnamomum burmannii*) from Sulawesi showed an inhibition zone on *Staphylococcus aureus*. Sandalwood essential oil has a high antibacterial ability, especially at high concentrations (Xiao *et al*. 2020). The study by Pratiwi *et al.* (2015) reported that cinnamon and massoia essential oils have the potential to inhibit planktonic and biofilm growth of two opportunistic pathogenic bacteria, *Pseudomonas aeruginosa* PAO 1 and *Staphylococcus aureus* Cowan I.

In measuring the diameters of the inhibition zones in the antibacterial activity test against *S. aureus* ATCC 25923 bacteria, soaps having the diameter of the inhibition zone exceeding the positive control were those containing 3% massoia essential oil (F7), 1% cinnamon (F2), and 3% cinnamon (F3). Based on the transparency test, the resulting soaps were categorized as transparent because the researchers could read the 14-point fonts through each piece of soap with a thickness of 0.25 inches. Based on SNI 3532-2016, a soap should have a pH of 9-11. Based on the pH test of transparent herbal soaps, the soaps met the set quality standards; each soap had a pH of 9, which was in the range of 9-11.

In terms of foam stability, the formulations varied and were not much different from each other, but they were already good, in the range of 60-70%. The high foam stability of soap is determined by the low amount of lost foam (Sawiji *et al*. 2021). A soap is said to have good foam stability if it has a foam stability value range of 60-70% after being left for 5 minutes (DeRagon *et al.* 1968). With the addition of essential oils and increasing concentrations of essential oils, the stability value of the foam decreased.

The water content of the transparent herbal soaps produced in this study ranged from 13.02-13.22%, thus in accordance with SNI 3532:2016, which states that the water content of soap should not be more than 15%. The more essential oils added, the less water content the soaps have because essential oils are hydrophobic (Ayu *et al*. 2018).

The saponification number of the transparent herbal soaps produced in this study ranged from 197.44 to 204.31 mg/g, in accordance with SNI 06-3532-1994, which states that a good saponification number ranges from 196 to 206 mg/g (Irmayanti *et al*. 2014). The more oil contained in the soap, the more alkaline are needed to saponify the oil, so the saponification number is also higher.

Of all the transparent herbal soap formulations, the best one was the transparent herbal soap with the addition of 3% massoia essential oil (F7) because it had the highest antibacterial activity with an average inhibition zone diameter of 16.47 mm and was categorized as strong. The compound that acts as an antibacterial agent and has the highest levels in massoia essential oil is massoia lactone compound. The addition of 3% massoia essential oil got the highest inhibitory power, followed by that of 3% cinnamon essential oil and 3% sandalwood essential oil, getting 15.37 mm and 12.19 mm, respectively, both of which were considered strong as well. The quality test results, including transparency, pH, foam stability, water content, and saponification number, indicated that the formulation was of good quality and was in accordance with SNI.

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