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Synthesis and Characterization of Cinnamon Bar Soap from Waste and New Cooking Oils: A Comparative Study

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Waste cooking oil, cinnamon, soap, NaOH, cold process

Abstract

Improper disposal of waste cooking oil led to environmental risks. Converting waste cooking oil into handmade soap, especially by adding cinnamon, offers a sustainable reuse method. This study investigates cinnamon's impact on soap's cleaning ability by using cold process method. The fundamental materials used in this process such cooking oil, sodium hydroxide (NaOH), distilled water, and cinnamon. Cinnamon was added with variation concentration from 0g, 3g, 6g, 9g, and 12g for both using new cooking oil (NCO) and waste cooking oil (WCO). Soaps were evaluated for colour, pH value, FTIR analysis, moisture content, swelling test, and stain removal test. The results indicate that the soap sample from new and waste oil without cinnamon appeared nearly white, while soap samples with highest concentration of cinnamon were dark brown. Both soap from new and waste oil had a pH level of 8 and a moisture content of 11.11%. Cinnamon bar soap using new oil and 6 grams of cinnamon has the highest degradation rate at 12.31%, and cinnamon bar soap using waste oil and 3 grams of cinnamon has the lowest at 6.46%. The soap in vinegar solution showed the most chemical reaction with a pH level of 2, while the soap observed remain stable in the salt solution due to its pH value of 9. Both bar soaps from NCO and WCO are equally effective at removing stains. Specifically, both soap from new and waste oil removed 94% of soy sauce stains. For chili sauce stains, the soap using new oil removed 87%, while the soap using waste oil removed 88%. However, for lipstick stains, both soaps only managed to remove 80% of the stain. This study suggested that bar soaps made from WCO with cinnamon additives can be used as raw material in production of high-quality soap which promotes environmental responsibility and contributes to sustainable waste management.

1. Introduction

Soap is an everyday and essential product that has been an integral part of human hygiene and daily life for centuries. Whether in the form of a simple bar, a liquid dispenser, or a specialized beauty product, soap serves a vital role in maintaining cleanliness and promoting good health. Soap is a substance that, when dissolved in water, it has the ability to remove dirt from surfaces such as human skin, textiles, and other solids particle [1]. In the modern world, soap comes in various shapes, sizes, and purposes. There are soaps for sensitive skin that promote relaxation or invigoration and even eco-friendly options designed to minimize environmental impact. Moreover, antibacterial soaps are vital in healthcare environments because they prioritize hygiene and are enhanced with antimicrobial ingredients [2]. Glycerin soaps are well regarded for their moisturizing qualities, making them mild choices ideal for anyone with dry or sensitive skin [3].

Typically, soaps are created through a chemical reaction involving alkaline substances and fatty acids found in fats or oil which result in the formation of salts of free fatty acids [4]. Waste cooking oil (WCO) is one of the examples of oil used in creating soap. It is common for WCO to be disposed of by pouring it down sinks and drainage systems, where it eventually goes to the sewage system. Improper disposal of WCO by pouring it down drains often leads to environmental pollution [5]. After being used multiple times in food preparation, these fats and oils become unsuitable for consumption due to oxidation, the accumulation of impurities, and foreign matter where they are leading to their disposal [6-7].

Pollution from WCO occurs when plants and animals come into contact with oil, leading to harmful effects on the environment, particularly aquatic life. This prevailing trend underscores the importance of addressing and managing the environmental impact associated with the disposal and treatment of WCO. Moreover, sodium hydroxide (NaOH) is an essential ingredient in the soap making process. It plays a role in the saponification process, reacting with fats and oils to produce soap. During the soap making process, a diluted lye solution is added to the oils to create a thick mixture. NaOH helps break down fats and oils into water-soluble sodium salts were making soap become more effective in cleansing. It is also cost-effective, making it an ideal ingredient for homemade soap [8].

Furthermore, to make the soap more effective, the addition of natural and synthetic additives will improve the qualities, look, and performance of the soap. Natural additives are renewable, biodegradable, and have a lower environmental impact compared to synthetic additives. The use of synthetic additives can have harmful effects on both humans and the environment. For humans, these additives can cause conditions like dermatitis and fatal anaphylaxis [9-10]. Turmeric, garlic, and cinnamon were examples of natural additives. Cinnamon was chosen to be used as an additive because it has many potential advantages for the skin, and it contains antibacterial qualities that may help guard against infections [11]. Cinnamon powder may also be used as a light exfoliator, assisting in the elimination of dead skin cells for smoother skin.

In this study, sustainable additives in the form of cinnamon bar soap were synthesized by using new cooking oil (NCO) and WCO. The cold process method was selected for this study due to the slower saponification reaction, allowing for greater control over the soap production process. Various quantities of cinnamon weights, which are 0 g, 3 g, 6 g, 9 g, and 12 g, will be included in the soap production process to assess the effects of cinnamon on the soap. Next, to assess the stain removal capabilities of cinnamon bar soaps, a standardized stain removal test was conducted using common household stains such as soy sauce, chili sauce, and lipstick. The soap bars were then used to wash the stained fabrics under controlled conditions.

2. Materials and Methods

2.1 Material

The bar soap was created using a mixture of cooking oil, which is NCO and WCO, sodium hydroxide (NaOH), and cinnamon as an additive. The WCO was sourced from stalls around Taman Universiti, Parit Raja, while the NCO (Saji) and cinnamon powder (McCormick Herb and Spices) were bought at local supermarket around Parit Raja. Chemical substances used in this study such as sodium hydroxide (Emory), ethanolic potassium hydroxide (QRëC and HmbG Chemical), phenolphthalein (SAFENViO), and ethanol 95% (HmbG Chemical). All the chemicals used were analytical reagent-grade. Other materials used, such as vinegar (Hung Fong), sugar (MSM Prai), salt (Double Swallow), soy sauce (Nur), chili sauce (Puteri), and lipstick (Ireneda), are from the store around Taman Universiti, Parit Raja.

2.2 Preparation for Soap

To produce soap from WCO, ensure all equipment is clean and functional. First, 300 grams of WCO were measured and transferred into a clean beaker. In a separate beaker, 88 grams of distilled water were measured. Then, 44 grams of NaOH were weighed and combined with distilled water, stirring continuously until the mixture warms up and turns transparent, indicating complete dissolution of the NaOH. The warm NaOH solution was then slowly added to the WCO, with consistent stirring, to create a homogeneous mixture. After about 10 minutes, the mixture was poured into a mold to cool and solidify. This process was repeated for four additional samples, with different amounts of cinnamon added to each WCO batch to investigate differences in soap properties.

Similarly, the procedure was carried out with five samples using NCO to observe variations in the soap's characteristics. Although the mixture solidified within 24 hours, it was not immediately usable. It had to be cured undisturbed for 3 to 4 weeks to allow the saponification process to fully complete. This curing phase was essential to make the soap safe and effective. After this period, the soap bars were fully solidified and ready for use. The soap sample composition can be referred to in Table 1.

Table 1 *Soap sample composition*

Sample Name	Additives		Type
	Amount (g)	Weight of Additives in (wt%)	
NC00	0	0	-
NC03	3	0.69	Cinnamon
NC06	6	1.39	Cinnamon
NC09	9	2.08	Cinnamon
NC12	12	2.78	Cinnamon
WC00	0	0	-
WC03	3	0.69	Cinnamon
WC06	6	1.39	Cinnamon
WC09	9	2.08	Cinnamon
WC12	12	2.78	Cinnamon

2.3 Physicochemical Analysis

Physicochemical analysis was conducted to understand the physical and chemical characteristics of substances, providing insights into product behavior. Its importance was recognized across both scientific and industrial fields. The analysis of oil and soap samples included various physical assessments, such as color, density, and hardness measurements, along with chemical analyses using Fourier Transform-infrared (FTIR). The pH value, Free Fatty Acid (FFA) content, Saponification value (SV), moisture content, swelling test, and stain removal test for bar soap were also determined. These methods allowed for a detailed understanding of the sample's compositions and properties.

2.3.1 Density

About 30 ml of NCO and WCO were weighed and tested using the Mettler Toledo machine. This recorded volume of density was then applied to Eq. (1), allowing for the calculation of the density to compare the result between the experiment and the theoretical value.

$$\rho = \alpha \frac{A - B}{V} + P_L \tag{1}$$

Where α is the balance of the correction factor (0.99985), A is the weight of the sinker in the air, B is the weight of the sinker in the liquid, V is the volume of the sinker, and P_L is the air density (0.0012 g/cm^3).

2.3.2 Hardness Test

The Shore durometer's operating stand had a 3 cm × 3 cm × 3 cm cube of bar soap placed on it. The needle of the Shore durometer was pressed onto the surface of the bar soap to obtain a value, and this step was repeated three times for each sample of bar soap.

2.3.3 pH Value

About 10 ml of cooking oil (NCO and WCO) was put on the plate, and the pH strip paper was dipped in the sample. For the bar soap, the soap samples are moistened with distilled water. Afterward, a pH strip is applied to the moistened side of the soap and wait for the pH strip to change in colour. Following this change, the resulting colour is matched against the colour chart provided with the pH strip.

2.3.4 Fourier Transform Infrared (FTIR)

For oil analysis, three drops of the sample were placed on the sample compartment and scanned, producing a wavenumber-to-transmittance graph. For the soap samples, the soaps were shaved and placed in the sample compartment and pressed using the auto sampler presser before scanning. The FTIR instrument examined a wavenumber range from 600 to 4000 cm^{-1}, using the Perkin Elmer Spectrum 100 model for the analysis.

2.3.5 Free Fatty Acid (FFA)

2 g of the oil sample was combined with 50 ml of isopropyl alcohol in test tubes. This mixture was then homogenized in a water bath at approximately 50°C. Next, a 0.5 ml drop of phenolphthalein indicator was added to the homogenized mixture, and the solution was briefly stirred. Titration was then performed by gradually adding a 0.1 N sodium hydroxide (NaOH) solution, prepared by dissolving 4 g of NaOH in 1 L of water. Titration continued until a permanent reddish or pink color emerged, indicating the completion of the neutralization process. The volume of NaOH used during this titration process was carefully measured and recorded, as this information is crucial for calculating the FFA content of the oil samples, as described in Eq. (2) [12].

$$\%\ \mathrm{FFA} = \frac{25.6\ \times \mathrm{N}\ \times \mathrm{V}}{\mathrm{w}} \quad (2)$$

where N is the normality (concentration) of NaOH, V is the volume of NaOH, and w is the weight of the oil used.

2.3.6 Saponification Value (SV)

A 1 g oil sample is placed in a 50-100 ml Erlenmeyer flask to conduct the saponification value test. The oil sample is then thoroughly mixed with 10 ml of a 0.5 N ethanolic potassium hydroxide (KOH) solution. The flask containing the mixture is then heated in a water bath maintained at a temperature between 80°C and 85°C for 30 minutes. This heating step facilitates the saponification process, where the esters present in the oil are hydrolyzed. After the heating step, the flask is cooled to 30-40°C. The resulting solution is then titrated with a 0.5 N standard hydrochloric acid (HCl) solution, using 2-3 drops of an appropriate indicator to determine the endpoint of the titration.

The volume of HCl consumed during the titration is a crucial measurement that will be used to calculate the saponification value of the oil sample, as per the established methodology. A blank test is also carried out alongside the sample, following the same procedure but without adding the oil, as a reference for any potential interferences or background reactions during titration [13]. This recorded volume was then applied to Eq. (3):

$$\mathrm{SV}\ (mg/g)\ = \frac{28.05\ \times (\mathrm{A} - \mathrm{B}) \times \mathrm{F}}{\mathrm{S}} \quad (3)$$

where S is for sample weight, A is for titration volume of blank (ml), B is for titration volume of sample (ml), and F is for factor of 0.5N HCI standard solution.

2.3.7 Moisture Content

The soap sample was prepared initially by grating and then weighing 10 g of the grated soap. After that, it was dried in an oven set at 100°C for 2 hours. Once the time was up, the soap was removed from the oven and left to cool. The dried soap sample was weighed, and the result was recorded [14]. By using Eq. (4), the moisture content was calculated:

$$\%\ \text{Moisture Content} = \left(\frac{w_2 - w_1}{w_2}\right) \times 100 \quad (4)$$

where w_1 is the weight of the soap after drying and w_2 is the weight of the soap before drying.

2.3.8 Swelling Test

A 2 cm × 2 cm × 2 cm cube of bar soap sample was immersed in the solution of sugar, salt, and vinegar. Then, the sample will be measured in terms of changes in dimensions, such as length, width, and thickness [15]. By using Eq. (5), the recorded measurement was calculated:

$$\text{Percentage of increment} = \left(\frac{V_f}{V_i}\right) \times 100\ \% \quad (5)$$

where, V_i is initial volume and V_f is the final volume.

2.4 Stain Removal Determination

In this experimental study, three types of stains (chili sauce, soy sauce, and lipstick) were applied to a plain white cloth to assess the effectiveness of different soap formulations in cleaning. After using the stains, the fabric was left untouched for a day to allow the stains to dry and set completely. The stain removal test involved soaking fabric samples with stains in bar soap solutions for 6 hours, and data was collected hourly during this process. The soap's ability to lift and remove stains was assessed, and the recorded values were used in eq. (6) to calculate the percentage of stain removal for the three stain types [16].

$$\text{Percentage of stain removal} = \left(\frac{d_i - d_f}{d_i}\right) \times 100\ \% \tag{6}$$

where, d_i is initial diameter and d_f is the final diameter.

3. Results and Discussion

3.1 Physicochemical Characteristics of the Oil

From the determination of oil, the NCO sample showed a "brighter" colour, while the WCO sample is proved to have "darker" colour. This visual disparity in appearance may indicate differences in the composition or processing of the two oils. The density measurements reveal that the NCO sample has a density of 0.907 g/cm^3, whereas the WCO sample has a slightly higher density of 0.911 g/cm^3. Density can offer insights into the molecular structure and potential applications of oils. Both oil samples have a pH value of 5, indicating a neutral acidity level which is a common trait for many types of oils.

The FFA percentages are different between the two samples, with NCO having 3.80% FFA and WCO having a higher FFA content of 5.12%. FFA levels can impact the stability, quality, and potential uses of the cooking oils. The saponification values (SV) also differ, with NCO having an SV of 42.08 mg/g and WCO having a lower SV of 28.05 mg/g. The saponification value serves an indicator of the average molecular weight of the fatty acids present in the oil, which can be relevant for certain applications such as soap-making or the production of other oleochemical products [17]. Table 2 shows the analysis of oil for NCO and WCO.

Table 2 *Oil analysis result*

Sample	Colour	Density (g/cm^3)	pH	FFA (%)	SV (mg/g)
NCO	Brighter	0.907	5	3.80	42.08
WCO	Darker	0.911	5	5.12	28.05

Fourier transform infrared was used to find the chemical properties of the soap. Fig. 1 show the FTIR results for two oil samples revealing six peaks for each sample. Notably, the range for each peak remains consistent across all oil samples. The infrared transmittance spectra of NCO and WCO both show broad, intense peaks around 3200-3550 cm^{-1}, likely corresponding to intermolecular hydrogen-bonded hydroxyl (OH) groups. Sharp peaks at 2863.19 cm^{-1} and 2922.33 cm^{-1} are potentially associated with C-CH3 and N-CH3 (aliphatic) vibrations. Peaks in the 1700-1900 cm^{-1} range may be attributed to nonconjugated C=O stretching vibrations. Additionally, sharp peaks at 1405.24 cm^{-1} and 1743.86 cm^{-1} are associated with C-OH stretching and C-O-C vibrations in esters for NCO, and 1465.19 cm^{-1} and 1743.71 cm^{-1} for WCO.

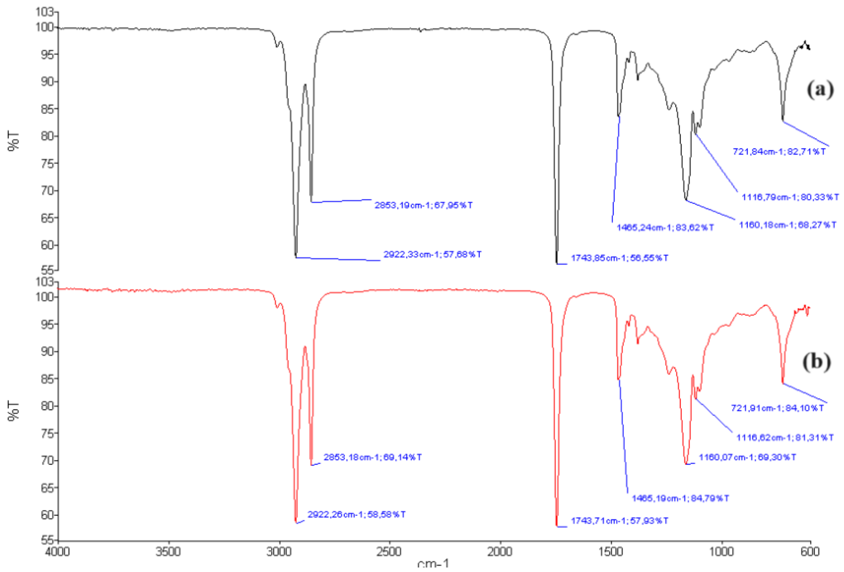


Fig. 1 *FTIR result for oil analysis; a) NCO b) WCO*

3.2 Soap Characterization

In this section, a comprehensive analysis of the bar soap was conducted through physical and chemical testing. This included assessing its colour comparison, texture, and hardness for physical tests, as well as determining its pH level, conducting Fourier Transform-Infrared (FTIR) spectroscopy, and performing a swelling test for chemical tests. Our extensive review enhances our understanding of the soap's characteristics and its potential uses.

3.2.1 Colour Comparison

Fig. 2 shows that the NC00 sample is nearly white, indicating a pure or minimally processed soap with little to no additional coloring or impurities. As the weight of additives increases, the soap samples become increasingly beige or light brown, which suggests the introduction of more additives that affect the soap's appearance. The NC09 sample has a more pronounced brownish hue, reflecting a higher concentration of these added substances. Finally, the NC12 sample is the darkest, with a deep brown colour, implying the highest levels of additives or potentially longer processing or reaction times.

Next, Fig. 3 shows soap samples labeled WC00 through WC12, with a gradual colour progression from left to right. WC00 is nearly white, indicating minimal processing, while WC12 is the darkest brown, suggesting higher concentrations of added substances. The colour change likely reflects varying ingredient concentrations and can indicate soap quality and saponification effectiveness. The progressive darkening of the soap samples from NC00 to NC12 and WC00 to WC12 likely correlates with increasing concentrations of certain components in the formulation, such as higher amounts of additives used during the soap-making process. This colour change can be indicative of the soap's quality and purity, as well as the effectiveness of the saponification process.

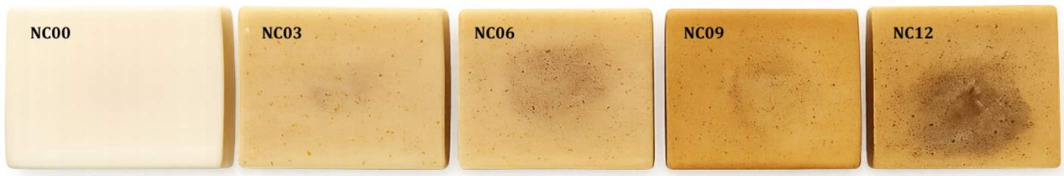


Fig. 2 *Bar soap sample made from NCO*

Fig. 3 *Bar soap sample made from WCO*

3.2.2 Comparison of pH Value for Different Weights of Additives

Table 3 showcases data on soap samples produced using two varieties of cooking oils, which are NCO and WCO, combined with varying concentrations of cinnamon as an additive. The samples are labeled as follows, NC00 and WC00 with 0% cinnamon, NC03 and WC03 with 0.69% cinnamon, NC06 and WC06 with 1.39% cinnamon, NC09 and WC09 with 2.08% cinnamon, and NC12 and WC12 with 2.78% cinnamon.

Table 3 *pH value for bar soap*

Sample Name	Weight of Additives in		pH Value
	wt%	gram (g)	
NC00	0	0	8
NC03	0.69	3	8
NC06	1.39	6	8
NC09	2.08	9	8
NC12	2.78	12	8
WC00	0	0	8
WC03	0.69	3	8
WC06	1.39	6	8
WC09	2.08	9	8
WC12	2.78	12	8

Despite the increment addition of cinnamon, the pH value for all samples consistently remains at 8, indicating a stable alkalinity level. This pH consistency suggests that introducing different cinnamon quantities does not notably affect the soap's pH value. NCO leads to a predictable and steady saponification process, yielding soaps of consistent quality. On the other hand, impurities in WCO may interfere with the saponification process, leading to soaps of inconsistent quality [18]. However, incorporating cinnamon can enhance the soap's characteristics, such as its fragrance and colour, without causing significant disruptions to the saponification process because the pH remains stable across all samples.

3.2.3 Fourier Transform-Infrared (FTIR) for Bar Soap

Fig. 4 and Fig. 5 show FTIR analysis results comparing soaps made with NCO and WCO. They highlight differences and similarities in the soap samples' spectra, offering insight into the resulting chemical structures and potential functional variations.

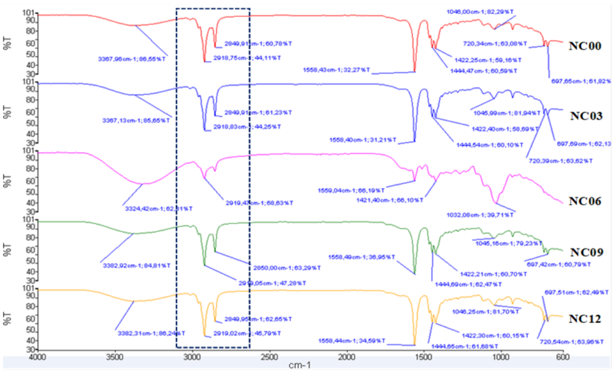


Fig. 4 *FTIR result for bar soap using NCO*

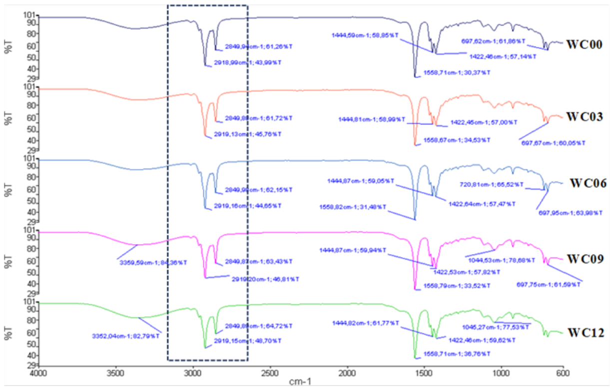


Fig. 5 *FTIR result for bar soap using WCO*

The dashed box in Fig. 4 highlights the 2800-3000 cm^{-1} region in these spectra for soap using NCO. This range is usually linked to C-H stretching vibrations, specifically from aliphatic (saturated) hydrocarbon groups such as -CH2- and -CH3. The clear peaks in this area likely correspond to these types of C-H stretching modes. The position and intensity of these peaks can offer insights into the types and surroundings of the hydrocarbon groups present in the samples. For instance, the 2863 cm^{-1} and 2922 cm^{-1} peaks might be due to C-CH3 and N-CH3 vibrations, respectively.

In Fig. 5, the dashed box highlights the 2800-3000 cm^{-1} region in the spectra for soap using WCO. This region typically shows C-H stretching vibrations, particularly from aliphatic (saturated) hydrocarbon groups like -CH2- and -CH3. The sharp peaks in this region correspond to these types of C-H stretching vibrations. The position and intensity of these peaks can give information about the types and environments of the hydrocarbon groups present in the samples. For example, the 2863 cm^{-1} and 2922 cm^{-1} peaks can be attributed to C-CH3 and N-CH3 vibrations, respectively. By examining these C-H stretching peaks and other features in the broader infrared spectra, researchers can gain insights into the chemical composition and structural characteristics of the analysed materials.

3.2.4 Degradation of Bar Soap

Fig. 6 shows the graph's weight loss is caused by water evaporation from the soap over 12-week period, which decreases its weight over time. By the end of 12 weeks, the rate of degradation is higher in NCO soap sample when compared to WCO soap sample. This trend of degradation continuous increase as the amount of cinnamon present in the samples increases from 0 g to 12 g, applicable to both NCO and WCO samples. This indicates a clear correlation between the quantity of cinnamon added and the degree of degradation, with samples containing a higher amount of cinnamon exhibiting a greater rate of degradation. The percentage of degradation is generally higher for the NCO samples compared to the WCO samples. Degradation increases as the cinnamon concentration increase, indicating that higher-numbered samples degrade more. The highest degradation is in NC12 at 12.31% and WC09 at 11.11%, while the lowest is in NC03 at 9.34% and WC03 at 6.46%.

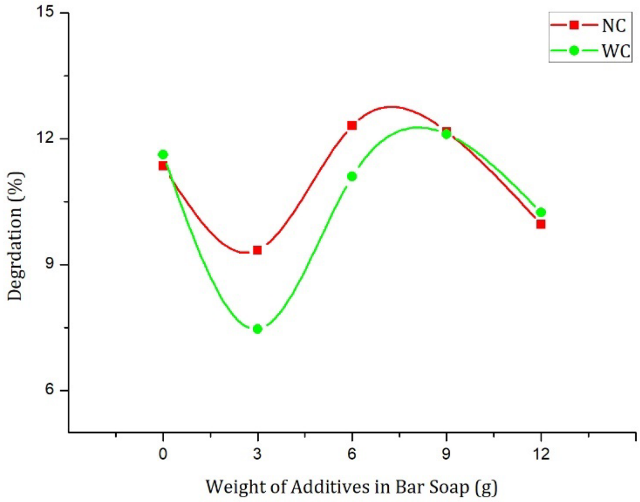


Fig. 6 *Degradation of bar soap sample*

3.2.5 Evaluation of Bar Soap Degradation, Moisture Content, and Hardness Characteristics

Table 4 presents properties of the bar soap, which highlight significant variations in structural integrity and wear resistance among the bar soap samples. The sample NC06 has the highest degradation rate at 12.31%, indicating pronounced changes in shape, size, and overall structural integrity over time. On the other hand, the sample with the lowest degradation rate is WC03 at 6.46%, suggesting that it maintained better structural stability during use or storage. These degradation characteristics are crucial for determining the expected lifespan and durability of bar soaps. Soaps with lower degradation rates would likely provide longer lasting and more consistent user experience than those with higher degradation rates.

The moisture content of bar soap is an important quality parameter that affects its usability, texture, shelf life, and overall consumer satisfaction. According to the results in Table 4, the moisture content analysis of bar soap samples revealed a consistent weight loss of 1 g across all samples, resulting in a calculated moisture content of 11.11% for each soap sample. Soaps with lower moisture content are likely to last longer, as they are less likely to dissolve quickly when exposed to water. On the other hand, soaps with higher moisture content create a richer lather but tend to dissolve faster, which could lead to a shorter lifespan if not stored properly [19]. The hardness values shown in the Table 4 provide understanding of the physical firmness and perceived quality of the bar soap samples. The hardness range spans from 6.00 for the softer WC03 sample to 7.67 for the firmer NC06 sample.

Table 4 *Properties of bar soap*

Sample Name	Degradation (%)	Moisture Content (%)	Hardness
NC00	11.35	11.11	6.66
NC03	9.34	11.11	7.00
NC06	12.31	11.11	7.67
NC09	12.17	11.11	6.33
NC12	9.96	11.11	6.67
WC00	10.62	11.11	6.67
WC03	6.46	11.11	6.00
WC06	10.10	11.11	7.33
WC09	11.11	11.11	5.67
WC12	9.24	11.11	7.00

The bar soap demonstrates an inverse relationship between degradation and hardness. Soaps with lower degradation rates, such as NC03 and WC03, exhibit higher hardness values, while those with higher degradation rates, like NC00, NC09, and WC09, have lower hardness. This suggests that bar soaps with a sturdier and more compact structure are better at withstanding physical breakdown and maintaining their shape and integrity over time. Soaps with harder and more durable formulations are likely to provide a longer-lasting user experience compared to softer, more degradable soaps. However, the hardness values show more variation, ranging from 6.00 to 7.67. This suggests that the hardness of bar soaps is not solely dependent on the moisture content but is likely influenced by other factors, such as the type and ratio of surfactants, the inclusion of hardening agents, and the overall formulation.

3.2.6 Swelling Test

The graph in Fig. 7, illustrating the increment of soap samples in sugar solution, shows a more inconsistent pattern than the data for vinegar solution samples. The WC samples exhibit more significant variability, some show higher increment percentages than the NC counterparts, while others demonstrate lower increment levels. Overall, the sugar solution's increment levels are lower than the vinegar solution, suggesting that the sugar environment may be less harsh for soap formulations. However, the lack of a clear trend between the NC and WC samples implies that other factors, such as specific additives, may contribute to a more significant role in determining the stability of the soaps in a sugar solution.

Next, Fig. 8 shows that the soap samples in salt solution had a very different pattern from the vinegar and sugar solution data. In this case, the increment percentages for all samples, whether NC or WC bar soap samples, were consistently low which around 1%. This indicates that the salt solution had minimal impact on the increment of the bar soap samples. The stability of the soaps is mainly unaffected by salt in the solution which suggests that this is a more favorable environment for maintaining the integrity of the bar soap formulations.

Furthermore, the graph displayed in Fig. 9 was the soap samples in a vinegar solution clearly shows a noticeable difference in the increment pattern. The WC samples generally show higher percentages than the NC samples across all sample numbers. This proved that the WC soaps are more prone to absorb when soaked in a vinegar solution. The increment profiles also correlate with the sample number, with higher-numbered samples exhibiting higher increment percentages. This suggests that the more complex or processed soap formulations are less stable in the vinegar solution compared to the simpler, lower-numbered versions.

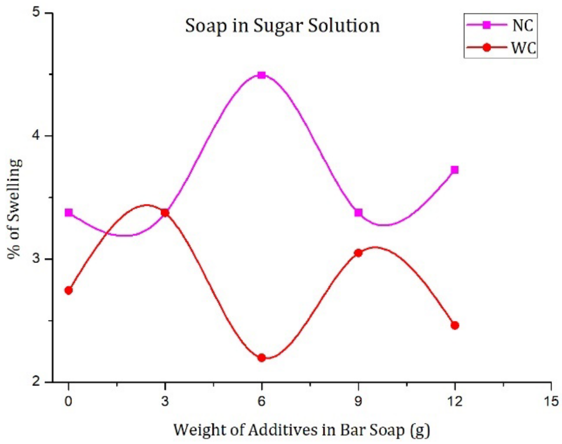


Fig. 7 *Immerse in sugar solution*

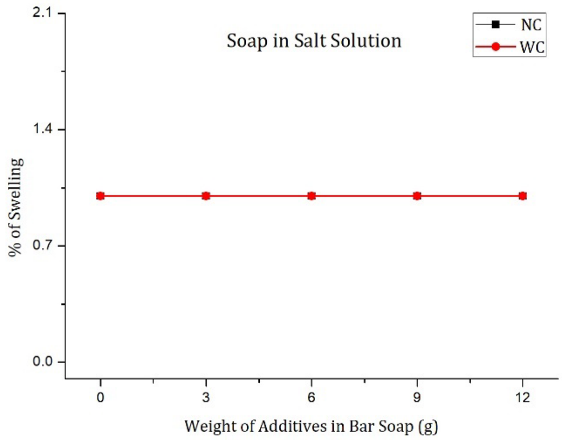


Fig. 8 *Immerse in salt solution*

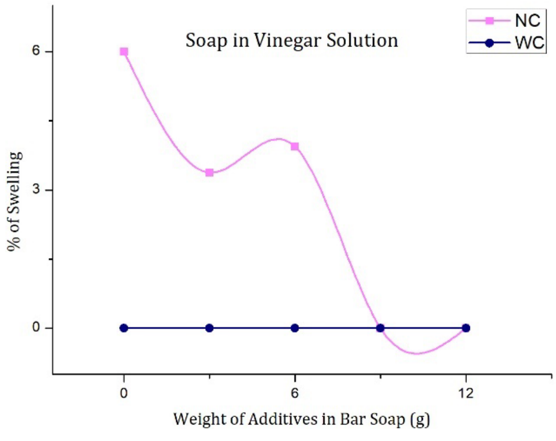


Fig. 9 *Immerse in vinegar solution*

3.3 Stain Removal Analysis

The analysis showed that the performance of all soap samples was consistent when it came to soy sauce and chili sauce stains. They managed to clean these stains to a similar degree. In Fig. 10, the graph presents soy sauce stain removal shows a similar trend, with WC bar soaps demonstrating comparable and superior performance to NC bar soaps in some cases. The standout samples are again NC12 and WC12, which achieve stain removal percentages exceeding 90%. Fig. 11, the chili sauce stain removal graph shows that NC and WC bar soaps exhibit strong cleaning capabilities, with most samples achieving stain removal percentages above 80%. Notably, the WC bar soaps perform on par with, or even outperform, the NC bar soap. The highest-performing samples are NC12 and WC12, which surpass 85% stain removal.

However, in Fig. 12, the lipstick stains presented a notable challenge. The lipstick stain removal graph further reinforces the findings, with the WC bar soaps exhibiting impressive cleaning abilities. While the NC bar soaps generally show good stain removal. But the highest cinnamon concentration, NC12 and WC12 has outshine the other soap samples by achieving removal rates above 80%. This difficulty in removing lipstick stains can be attributed to their composition, which includes a blend of wax and oils that contribute to their smooth texture [16], [20].

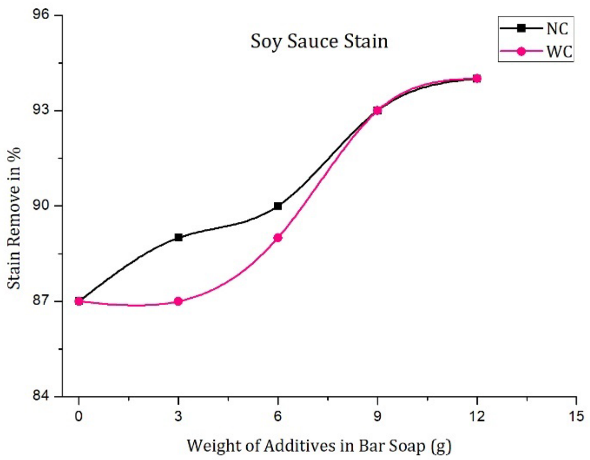


Fig. 10 *Soy sauce stain*

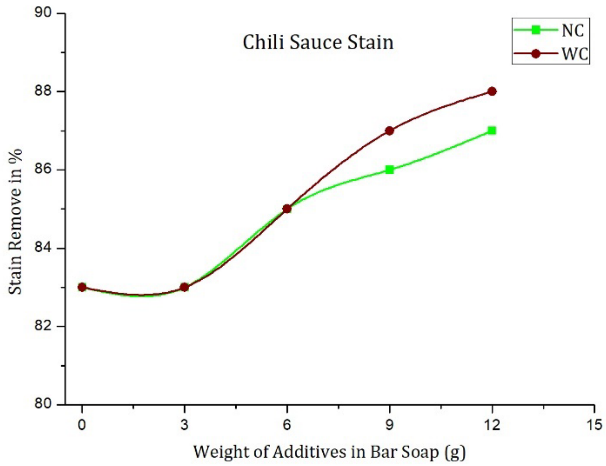


Fig. 11 *Chili sauce stain*

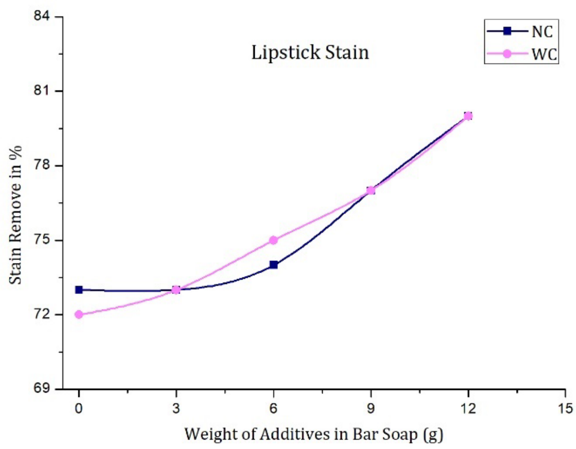
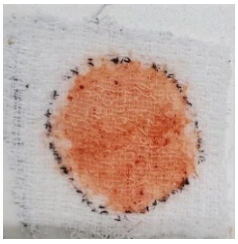
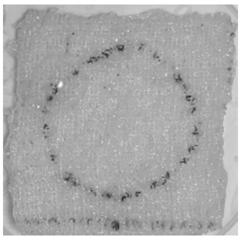
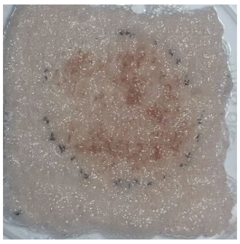


Fig. 12 *Lipstick stain*

Across all three stain types, the data strongly suggests that the WC bar soaps can be a viable and sustainable alternative to the NC bar soap, as they demonstrate comparable or even superior stain removal capabilities. This information could be precious for consumers seeking efficient and environmentally conscious bar soap products and for manufacturers aiming to optimize their formulations and production processes to achieve superior cleaning performance while promoting sustainability.

Table 5 comprehensively evaluates how well the cinnamon soap performed in removing three specific stains such as soy sauce, chili sauce, and lipstick. The table explains how the soap effectively eliminated each type of stain using the combined effects of NCO and WCO. By thoroughly analyzing the data in Table 5, it will provide a comprehensive understanding of the soap's effectiveness in removing stains and its potential uses for various household cleaning tasks.

Table 5 *Stain removal analysis*

Sample	Stain	Before	After	Description
NC12	Soy Sauce			The stain was 94% removed.
WC12				The stain was 94% removed.
NC 12	Chili Sauce			The stain was 87% removed.
WC12				The stain was 88% removed.
NC12	Lipstick			The stain was 80% removed.
WC12				The stain was 80% removed.

4. Conclusions

This study provides a comprehensive comparison of cinnamon bar soaps made from both NCO and WCO using cold process methods. The findings demonstrate that incorporating cinnamon at varying concentration does not alter the stable alkalinity (pH 8) of the soaps which ensure consistent soap quality. Degradation rates varied among samples, with NC06 showing the highest rate (12.31%) and WC03 the lowest (6.46%), indicating that WCO-based soaps can possess greater structural stability under certain conditions. All samples presented uniform moisture content (11.11%), and hardness values ranged from 6.00 to 7.67, underscoring differences in texture and durability across formulations. Swelling test revealed that bar soap was minimally affected by salt solution, while acidic environments (vinegar) led to increased breakdown, especially in soaps with higher additive content. This highlights the importance of formulation balance for product longevity in different usage conditions. Cinnamon proved to be an effective, natural additive, offering antioxidant and antibacterial benefits while being cost-efficient compared to synthetic chemicals. Crucially, stain removal tests confirmed that both WCO and NCO-based cinnamon soaps performed equally well, achieving up to 94% removal of soy sauce stains, 87%-88% for chili sauce, and 80% for lipstick stains. These results underscore the potential of reusing WCO for high-quality soap production without compromising cleaning effectiveness, thereby supporting sustainable waste management practices. By utilizing waste oils and natural additives, this study advances environmentally friendly alternatives in soap manufacturing and provides a practical solution for reducing ecological impact.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Mohd Nur Izzuddin Rosman;* ***data collection:*** *Mohd Nur Izzuddin Rosman;* ***analysis and interpretation of results:*** *Mohd Nur Izzuddin Rosman, Siti Aida Ibrahim;* ***draft manuscript preparation:*** *Mohd Nur Izzuddin Rosman, Siti Aida Ibrahim, Ainun Rahmahwati, Niki Prastomo. All authors reviewed the results and approved the final version of the manuscript.*

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