

Pomelo and Papaya Antibacterial Liquid Hand Soap

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ABSTRACT: This study investigated the formulation, antibacterial efficacy, and acceptability of a natural liquid hand soap developed from pomelo (*Citrus maxima*) peel and papaya (*Carica papaya*) leaf extracts. Motivated by the growing demand for sustainable and plant-based hygiene products, the research aimed to develop an eco-friendly and skin-compatible alternative to commercial soaps containing synthetic additives. Three formulations were prepared using standardized procedures involving lye preparation, aqueous extraction, and controlled soap formulation: T1 (70% pomelo, 30% papaya), T2 (50% pomelo, 50% papaya), and T3 (30% pomelo, 70% papaya). Antibacterial analysis was conducted at the Quirino State University–Diffun Research Facility, while acceptability was evaluated through sensory testing involving 30 respondents from three demographic groups. Results showed that all formulations exhibited inhibitory activity against *Escherichia coli*, with zones of inhibition measuring 17–19 mm, indicating the presence of bioactive phytochemicals with antimicrobial properties. Sensory evaluation revealed consistently high acceptability across key attributes, including cleansing, color, foaming, fragrance, lathering, and moisturizing. Treatment 3 achieved the highest overall acceptability ($M = 4.79$), suggesting that a greater proportion of papaya leaf extract enhances both functional and sensory performance. Although analysis of variance showed significant differences in lathering perception among expert evaluators for Treatments 2 and 3, all formulations remained classified as “Highly Acceptable.” Overall, the findings demonstrate that pomelo peel and papaya leaf extracts can be effectively integrated into a stable, natural, and functionally potent antibacterial liquid hand soap. The study underscores the potential of indigenous plant materials in the development of natural personal care products and supports initiatives promoting sustainable, healthconscious, and environmentally responsible hygiene solutions.

KEYWORDS: Pomelo peel extract, Papaya leaf extract, Antibacterial liquid hand soap, Natural formulation, Sensory evaluation, Plant-based hygiene products, Sustainable personal care.

1. INTRODUCTION

Hygiene and sanitation have been major concerns not only during pandemics but also in everyday life. In recent years, increasing attention has been directed toward the use of natural and locally available ingredients in personal care products, driven by growing concerns regarding sustainability, hygiene, and public health. Among these products, liquid hand soap has become indispensable in daily life, particularly due to the global emphasis on hand hygiene as a means of maintaining personal cleanliness and preventing disease transmission. However, many commercially available hand soaps contain synthetic ingredients that may, over time, cause skin irritation and pose risks to environmental health. Recent research has increasingly emphasized the use of natural and locally available plant materials in the development of personal care products. Although numerous studies have documented the antimicrobial properties of papaya (*Carica papaya*) leaves and pomelo (*Citrus maxima*) peels, most of these investigations focus on isolated extracts or laboratory-based antimicrobial screening. There remains a notable research gap in integrating these locally abundant materials into a functional, consumer-acceptable liquid hand soap formulation, particularly in varying proportions, and evaluating its antibacterial efficacy, cost, and user acceptability. Addressing this gap is essential to bridging the divide between laboratory findings and practical, community-level applications (Ayad et al., 2017; Pino et al., 2015; Ajiboye & Olawoyin, 2020). Papaya leaves are recognized for their antimicrobial, antioxidant, and antiinflammatory properties due to their rich phytochemical content, which includes flavonoids, alkaloids, tannins, saponins, and phenolic compounds. These bioactive substances have demonstrated inhibitory effects against common pathogenic microorganisms such as *Escherichia coli* and *Staphylococcus aureus*, making papaya leaves a promising natural ingredient for antibacterial hand hygiene products (Ayad et al., 2017). Similarly, pomelo peels—often discarded as agricultural waste—contain essential oils and bioactive compounds with documented antibacterial activity, particularly against skin associated bacteria.

Despite their proven biological properties, limited studies have explored the combined use of papaya leaves and pomelo peels in liquid hand soap formulations, nor have they adequately examined user acceptability in terms of cleansing ability, fragrance, foaming, moisturizing effect, and overall sensory attributes across different age groups. Furthermore, there is insufficient research

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evaluating the feasibility of producing such natural soaps within school or community settings, including cost considerations (Pratiwi et al., 2023).

In response to these gaps, this study focused on the formulation of a pomelo and papaya antibacterial liquid hand soap using varying treatment ratios to determine its antibacterial properties, general acceptability among different groups of users, and cost of production. The study aimed to contribute practical evidence supporting the use of locally available plant resources as sustainable alternatives to synthetic-based commercial soaps. By aligning natural product development with public health needs, environmental sustainability, and community accessibility, the study supports Sustainable Development Goals (SDGs) and advances innovative, eco-friendly solutions for improving hygiene practices in school and community settings.

2. RELATED LITERATURE

Formulations of natural liquid hand soap are gaining increasing popularity due to their ability to cleanse and protect the skin while minimizing adverse effects. Ingredients such as fruit peels and medicinal plant leaves contain compounds with proven antibacterial and cleansing properties. This study focuses on papaya (*Carica papaya*) leaves and pomelo (*Citrus maxima*) peels, both recognized for their traditional and practical applications in skin care and home remedies. The literature reviewed in this chapter provides a deeper understanding of their phytochemical constituents and their potential use in the formulation of natural hand soaps.

Hand hygiene is widely recognized as one of the most effective measures in preventing the transmission of communicable diseases. Regular handwashing with soap and water significantly reduces the spread of bacteria and viruses, particularly in high-contact settings such as schools and public institutions. The Department of Health emphasizes proper handwashing as a fundamental practice in maintaining personal hygiene and public health (Department of Health, 2021).

Among various cleansing products, liquid hand soap is commonly preferred due to its hygienic dispensing, convenience, and suitability for frequent use. Compared to bar soaps, liquid hand soaps reduce the risk of cross-contamination and are therefore more appropriate for shared environments (Alexander et al., 2019).

2.1 Herbal-Based Liquid Hand Soaps

Formulations of natural liquid hand soaps are gaining increasing popularity due to their ability to cleanse and protect the skin while minimizing adverse effects. Unlike conventional soaps that rely on synthetic chemicals, herbal liquid hand soaps are produced using plant-based materials. Increased awareness of the potential harmful effects of synthetic antibacterial agents such as parabens and triclosan—which may cause skin irritation and contribute to antibiotic resistance—has driven consumer preference toward natural alternatives (Gupta & Dubey, 2018).

Also, Herbal ingredients are generally biodegradable, nontoxic, and rich in phytochemicals such as flavonoids, alkaloids, tannins, and saponins, which provide antioxidant and antibacterial properties (Rodriguez, 2021). Several studies report that herbal soaps present a lower risk of allergic reactions and demonstrate greater environmental compatibility compared to synthetic soaps (Smith & Jones, 2022; Lee et al., 2021).

With this, phytochemical analysis further supports the effectiveness of herbal products by validating the presence of bioactive compounds responsible for their antimicrobial activity (Doughari & Manzara, 2008). In addition to their cleansing capability, herbal soaps are valued for their skin-nourishing properties, as they contain natural emollients and enzymes that promote gentle exfoliation, skin regeneration, and suitability for frequent handwashing without excessive dryness.

2.2 Phytochemical Properties of Pomelo (*Citrus maxima*)

Pomelo (*Citrus maxima*), also known as shaddock, is the largest citrus fruit and is widely cultivated in tropical and subtropical regions, including the Philippines. Traditionally, pomelo has been used in folk medicine for managing digestive disorders, coughs, and skin-related ailments. Despite its common consumption, its thick peel is often discarded as agricultural waste (Pino et al., 2015). Recent studies have highlighted the potential value of pomelo peels due to their rich phytochemical content, offering opportunities for sustainable product development using waste materials (Ajiboye & Olawoyin, 2020).

Pomelo peels contain significant amounts of phenolic compounds, flavonoids, limonoids, and essential oils such as limonene and linalool, which contribute to antioxidant and antibacterial properties (Alavijeh et al., 2022). Flavonoids like naringin and hesperidin help inhibit bacterial growth by disrupting cell walls and metabolic processes (Ghasemzadeh & Jaafar, 2013). Additionally, pomelo peel extract provides a natural citrus fragrance, reducing the need for synthetic perfumes that may cause allergic reactions.

2.3 Medicinal Uses of Papaya (*Carica papaya*) Leaves

A popular tropical fruit in traditional medicine is the papaya. Alkaloids (including carpaine), flavonoids, tannins, and papain—a proteolytic enzyme with antibacterial and exfoliating qualities—are abundant in its leaves. These substances enable papaya leaves to effectively heal inflammation, wounds, and skin infections (Ajiboye & Olawoyin, 2020).

Papaya leaf extract is widely used in Do It Yourself and store-bought skincare products due to its antibacterial, antioxidant, and anti-inflammatory qualities. Its papain enzyme, which helps remove dead skin cells and encourages smooth, healthy skin, makes it the ideal addition to a hand cleansing recipe.

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Figure 1. Pomelo peels rich in antimicrobial flavonoids and essential oils.



Figure 2. Papaya leaves used for their antibacterial and exfoliating compounds.

2.4 Antibacterial Potential of Pomelo (*Citrus maxima*) Peel Extract in Liquid Hand Soap

In a study by Ochate et al. (2023), the antibacterial property of a liquid hand soap made using pomelo peel extract was evaluated. The study evaluated the number of bacterial colony-forming units before and after handwashing using a quantitative research approach. When compared to commercial hand soaps, the results showed a reduction in the number of bacteria after application, although the difference was not statistically significant. Pomelo peel's flavonoids, carotenoids, and phenolic acids were found to have antibacterial properties.

The antibacterial qualities of pomelo peel extract in liquid hand soap formulations were also evaluated in a different study that was published in the American Journal of Microbiological Research. According to the study, the soap made from pomelo efficiently decreased the number of bacteria, on par with commercial products. High approval was also noted by participants for both skin feel and aroma.

2.5 Antibacterial Activity of Papaya (*Carica papaya*) Leaf Extract in Liquid Soap

There are two varieties of soap: liquid soap and solid soap. Each type has features known as physicochemical characteristics, which are those that result in the distinctive physical characteristics of a substance (Kurniawati, 2021). The physical properties and antibacterial activity of liquid soap made with papaya leaf extract were the main subjects of research by Sari et al. (2024). The formulations were evaluated against *Staphylococcus aureus* and *Escherichia coli* using different extract concentrations. Because of phytochemicals such as alkaloids, flavonoids, and saponins, the results showed that the soap's antibacterial activity was increased at greater quantities of papaya leaf extract. The papaya plant's medicinally beneficial parts include the stem, Oktafani and Suwandi (2019) discuss fruit, sap, and leaves.

Papaya leaf extracts' antibacterial properties against bacterial and fungal infections were also assessed in a study that was published in the International Journal of Advanced Engineering Research and Science. The results supported the extract's usage in antibacterial compositions by confirming its capacity to inhibit microbial growth.

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3. METHODOLOGY

3.1 Research Design

The study employed a descriptive-experimental research design. The experimental component involved manipulating the treatment ratios of pomelo (*Citrus maxima*) peel and papaya (*Carica papaya*) leaf extracts to determine their effects on the antibacterial properties of the liquid hand soap. Experimental research allows the establishment of cause-and-effect relationships by controlling variables under systematic conditions (Creswell, 2018; Saha, 2024).

The descriptive component was used to assess the level of acceptability of the formulated soap in terms of cleansing ability, color, fragrance, foaming, lathering, and moisturizing effect based on respondents' perceptions. Descriptive research is appropriate for gathering and summarizing participants' evaluations of a product (Creswell & Creswell, 2018).

3.2 Locale of the Study

The study was conducted in various academic institutions and salons within City of Ilagan, Isabela. These locations were chosen due to their accessibility and the availability of respondents' who were knowledgeable about beauty care practices. were knowledgeable about beauty care procedures. Among the participating establishments were:

- San Rafael National and Vocational High School
- San Antonio National Agro-Industrial and Vocational High School
- Isabela State University – Ilagan Campus
- Isabela School of Arts and Trades
- Hair Studio Beauty Wellness Salon
- J Salon

These locations provided diverse participants including students, teachers, and professional beauty experts, ensuring a well-rounded product evaluation.

3.3 Selection and Description of Respondents

The respondents of this study were purposely selected to guarantee a wide variety of evaluations. A total of thirty (30) respondents were chosen and categorized as follows:

- Teenagers (13 – 19 years old). Ten respondents evaluated the product's effectiveness
- Adults (20 years old and above). Ten respondents represented general consumers who rated the product's effectiveness.
- Beauty Care Teachers/ Salon Employees. Ten respondents from experts assessed the product's effectiveness.

To ensure the accuracy and relevance of the feedback, the respondents were selected based on their regular use of hygiene and personal care products, particularly liquid hand soap.

Before performing the assessment, they were told how to correctly use the antibacterial hand soap. Using a Likert scale to gauge acceptance in terms of cleansing, color, foaming, fragrance, lathering, and moisturizing, their answers were collected by sensory evaluation and a standardized survey form. The study made sure that ethical principles, such as informed consent and confidentiality, were respected throughout the research process.

This methodology ensures a systematic and unbiased approach in evaluating the pomelo and papaya antibacterial liquid hand soap, contributing to the field of sustainable and plant-based beauty care products.

3.4 Materials

The following tools, equipment, and ingredients were used during the conduct of the study. Preparatory tools, mixing tools, measuring tools, extracting tools and packaging tools were utilized during the conduct of the study as shown in the table below.

Table 1. Tools and Equipment used in Developing Pomelo and Papaya Antibacterial Liquid Hand Soap

Preparatory Toos	Measuring Tools	Cooking Tools/Equipm ent	Extracting Tools/Equipment	Mixing Tools	Packaging Tools
Knife	Measuring cups	Stove	Blender	Spatula	Empty pump bottles
Chopping Board	Digital milligram scale	Pot	Strainer	Mixing Bowls	funnel
Mixing Bowls		Stick blender	Cheesecloth		
Wooden spoon/spatula		Thermometer			

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3.4.1 Ingredients

The table below presents the ingredients that were used in the formulation of the pomelo and papaya antibacterial liquid hand soap.

Table 2. Ingredients used in Developing Pomelo and Papaya Antibacterial Liquid Hand Soap

Ingredients	Measurements		
	Treatment 1	Treatment 2	Treatment 3
Potassium Hydroxide (KOH)	25 g	25 g	25 g
Virgin Coconut Oil (VCO)	109 ml	109 ml	109 ml
Distilled water	100 ml	100 ml	100 ml
Pomelo peel extract	66 ml	47 ml	27 ml
Papaya leaf extract	30 ml	49 ml	69 ml

3.4.2 Developmental Procedure

The following procedures were followed in the preparation and evaluation of the Pomelo and Papaya Antibacterial Liquid Hand Soap:

1. Preparation of KOH-Based Soap

- Weighted 50 ml of distilled water, 25 grams of potassium hydroxide (KOH) and 109 ml of Virgin Coconut Oil (VCO).
- Dissolved 25 grams of KOH to 50 ml of distilled water, stir until fully dissolved. Let it cool.
- Slowly added the cooled KOH solution into the warm VCO while stirring.
- Cooked the mixture on a low heat using double boiler. Use a stick blender to blend fully. The soap paste was undergone through phases (trace → thickening → gel-like → vaseline-like).
- Diluted the soap paste by adding 50 grams of warm distilled water gradually to turn it into liquid soap. Let it rest for 24 hours or overnight if needed.

2. Prepare pomelo peel and papaya leaf extracts

- Pomelo fruits and papaya leaves were harvested manually
- The pomelo peels and papaya leaves were thoroughly washed and sliced into small pieces to allow easier blending and extraction.
- The chopped pomelo peels and papaya leaves were extracted separately. For the papaya leaves, 5 ml of distilled water was added to the chopped leaves before blending. The mixture was then strained using a strainer/ cloth mitt. The strained liquid was poured back on the remaining chopped papaya leaves, blended and re-extracted until all possible extract was collected. The same extraction procedure was applied to the pomelo peels.

3. Preparing Pomelo and Papaya Antibacterial Liquid Hand Soap

- The pomelo peel extract, papaya leaf extract and soap base were measured accurately depending on the measurements of the three treatments (T1,T2,T3).
- A total of 150 ml of soap base was mixed separately with each of the three treatments.
- The final liquid hand soap was placed in clean, airtight containers and properly labeled.

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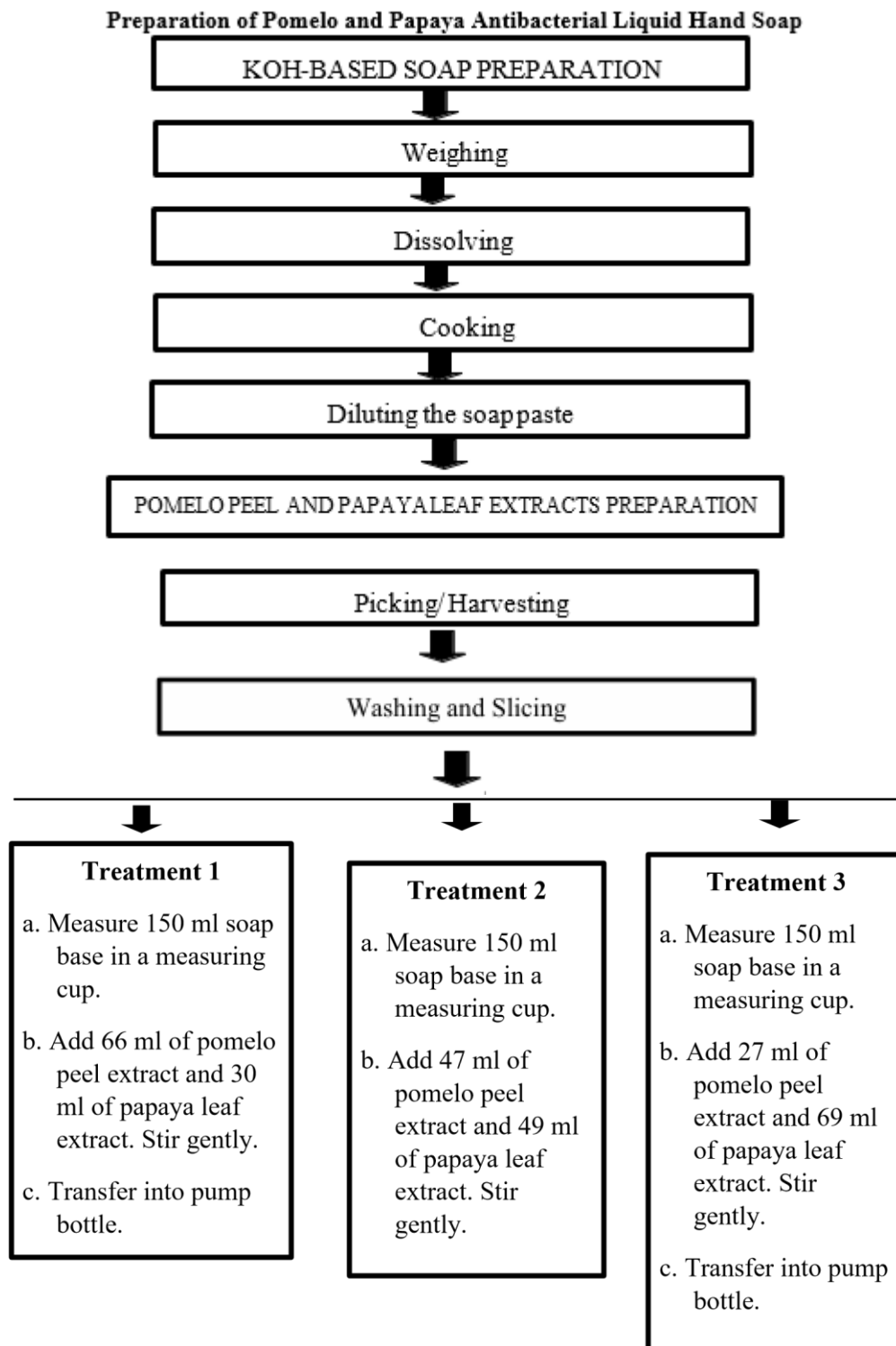


Figure 4. Production Flow Chart of Pomelo and Papaya Antibacterial Liquid Hand Soap

3.5 Data Gathering Instruments

The study utilized a Sensory Evaluation Form with a 5 - Likert Scale in assessing the effectiveness and acceptability of the Pomelo and Papaya Antibacterial Liquid Hand Soap. The Sensory Evaluation Form measured attributes such as cleansing, color, foaming, fragrance, lathering and moisturizing, while the Likert Scale Questionnaire quantified respondents' perceptions and satisfaction levels. These instruments ensured objective and systematic data collection, providing valuable insights into the product's effectiveness.

The Sensory Evaluation Form used in the study was adopted and modified from the Thesis of Apoy, Rebecca Ruiz, 2023 entitled "Calamansi (Microcarpa) Soap enhance with Blue Ternate Flower (Clitoria Ternatea)". The form was used to assess the effectiveness and acceptability of the Pomelo and Papaya Antibacterial Hand Soap, focusing on key criteria such as cleansing, color, foaming, fragrance, lathering and moisturizing, with a 5 – point Likert Scale for responses.

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This evaluation system enables the researcher to qualify respondents' preferences and analyze the overall acceptability of the product. By employing this structured rating approach, the study ensures a precise assessment of the sensory attributes and effectiveness of the Pomelo and Papaya Antibacterial Hand Soap, offering valuable perspectives on its potential as an affordable, eco-friendly alternative to commercial hand soap products.

Table 3: Scale and Numerical Rating on the Acceptability on the Pomelo and Papaya Antibacterial Liquid hand soap

Score Rating	Score Range	Descriptive Rating
5	4.20 – 5.00	Highly Acceptable
4	3.40 – 4.19	Acceptable
3	2.60 – 3.39	Moderately Acceptable
2	1.80 – 2.59	Slightly Acceptable
1	1.00 – 1.79	Not Acceptable

3.6 Data Gathering Procedure

Before the conduct of the study, a request letter along with a sample of the Pomelo and Papaya Liquid Hand Soap was submitted to the Quirino State University – Diffun Research Facility in Isabela for phytochemical analysis. The researcher sought permission from the school heads of San Rafael National and Vocational High School and San Antonio National Agro-Industrial and Vocational High School, Isabela State University, Hair Studio Salons and J Salon to conduct the study through sensorial evaluation. The respondents were categorized into three groups: (1) teenagers aged 13–19 years, (2) adults aged 20 years old and above, and (3) beauty care teachers and salon employees. After the necessary permissions were granted, the three soap samples were tested on the respondents for effectiveness, followed by the administration of the questionnaires.

3.7 Sensory Evaluation

The finished product was subjected to sensory evaluation. A total of thirty (30) evaluators from various age groups were selected and properly oriented on how to evaluate the products using a score code. The samples were then provided to the chosen evaluators for assessment.

Consequently, the evaluators tested the samples from each treatment. Data on cleansing, color, lathering, foaming, fragrance, and moisturizing effects of each developed product were collected and coded for statistical analysis.

3.8 Data Gathering Analysis and Statistical Tools Used

All the data from the questionnaire provided to the evaluators were analyzed and interpreted using the computer output from the Statistical Package for the Social Sciences (SPSS) software.

- Mean (M).** This tool was used to measure the level of acceptability of the pomelo and papaya liquid hand soap based on the respondents' age groups. The mean level of acceptability based on the following scale:
- Standard Deviation (SD).** This tool was used to determine the variability or spread of the acceptability scores around the mean, which helped assess the consistency of the participants' evaluations.
- One-Way Between Groups Analysis of Variance (ANOVA).** This tool was utilized to determine whether there were significant differences in the level of general acceptability of the pomelo and papaya liquid hand soap among the three age groups (teenagers, adults, and experts).
- Pos Hoc Analysis Using Tukey HSD.** This tool was utilized when the ANOVA revealed a significant difference between and among the level of general acceptability of the Pomelo and Papaya Antibacterial Hand Soap across the three age groups of respondents.

4. PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA

4.1 Presentation of Data

4.1.a Processes of Preparing Pomelo and Papaya Antibacterial Hand Soap

Preparing the Pomelo and Papaya Antibacterial Hand Soap involved several steps to ensure cleanliness, consistency and product stability. The process begins with lye preparation, in which 25 g of potassium hydroxide (KOH), 50 ml of distilled water and 109 ml of Virgin Coconut Oil (VCO) are precisely weighed, mirroring standard saponification methods used to create a stable soap base. The KOH is dissolved in water, cooled, and then slowly added to the warm VCO while stirring; the mixture is then cooked on low heat in a double boiler and blended using a stick blender. This cooking and blending process encourages the soap paste to pass through distinct phases—from trace to thickening to a gel-like and eventually vaseline-like consistency—ensuring uniform texture and proper saponification. After cooking, 100 g of warm distilled water is added gradually to dilute the paste into liquid form, and the mixture is allowed to rest, often overnight, for stabilization.

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For the pomelo peel and papaya leaf extracts preparation, fresh pomelo fruits and papaya leaves are harvested manually, washed, and sliced into small pieces to maximize the surface area for extraction. The chopped plant materials are then extracted separately: 5 mL of water is added to the papaya leaves before blending, and the mixture is strained through a cloth mitt; this extracted water is poured back over the remaining chopped papaya leaves and re-extracted in a repeated process to ensure maximal recovery of bioactive compounds. The same extraction procedure was applied with the chopped pomelo peels. This method of extraction is supported by studies demonstrating that pomelo (*Citrus maxima*) peel contains flavonoids and phenolic compounds with strong antibacterial activity (Filbert et al., 2022), and that papaya (*Carica papaya*) leaf extracts are rich in alkaloids, flavonoids, tannins, and saponins, which exhibit significant antibacterial action (Karo-Karo, Arianto, & Salim, 2023). Moreover, the use of a water-based extraction is scientifically justified by evidence showing that aqueous papaya leaf extracts can disrupt bacterial biofilms, such as those formed by *Pseudomonas aeruginosa*, reducing biofilm mass significantly (Kining, Falah, & Nurhidayat, 2022).

Finally, after extraction, the pomelo peel extract, papaya leaf extract, and soap base are accurately measured and combined, with 150 ml of soap base mixed separately with each of the three treatments. The mixtures are thoroughly blended to ensure complete integration of the extracts into the base, then transferred into clean, airtight pump containers and labeled appropriately. This step not only ensures consistency and reproducibility but also aligns with the literature on using plant-derived bioactive compounds in soap bases to create natural antibacterial formulations that are both effective and consumerfriendly (Filbert et al., 2022; Karo-Karo et al., 2023; Kining et al., 2022).

Table 4: Processes of Preparing Pomelo and Papaya Antibacterial Hand Soap

Process	Details
KOH- BASED SOAP PREPARATION	
Weigh	Weighed 50 ml of distilled water, 25 g potassium hydroxide (KOH) and 109 ml of Virgin Coconut Oil (VCO)
Dissolving	Dissolve 25 g of potassium hydroxide (KOH) in 50 mL of distilled water and stir until fully dissolved. Allow the solution to cool. The cooled KOH solution was then slowly added to the warm virgin coconut oil (VCO) while continuously stirring.
Cooking	Cooked the mixture on a low heat using a double boiler. Use a stick blender to blend. The soap paste was undergone through phases (trace ▶ thickening ▶ gel-liked ▶ vaseline-like).
Diluting	Add 50 ml warm distilled water to the soap paste gradually to turn it into liquid soap. Let it rest for 24 hours or overnight if needed.
POMELO PEEL AND PAPAYA LEAF EXTRACTS PREPARATION	
Picking/Harvesting	Pomelo fruits and papaya leaves were harvested manually
Washing and Slicing	The pomelo peels and papaya leaves were thoroughly washed and sliced into small pieces to allow easier blending and extraction.
Extraction Process	The chopped pomelo peels and papaya leaves were extracted separately. For the papaya leaves, 5 ml of water was added to the chopped leaves before blending. The mixture was then strained using a strainer or cloth mitt. The strained liquid was poured back onto the remaining chopped papaya leaves and re-extracted until all possible juice was collected. The same extraction procedure was applied to the chopped pomelo peels.
POMELO AND PAPAYA ANTIBACTERIAL LIQUID HAND SOAP PREPARATION	
Measuring	The pomelo peel extract, papaya leaf extract, and soap base were measured accurately for each treatment. For treatment 1, 66 ml pomelo peel extract, 30 ml papaya leaf extract and 150 ml soap base were used. For treatment 2, 47 ml of pomelo peel extract, 49 ml papaya leaf extract and 150 ml soap base were utilized. For treatment 3, 27 ml pomelo peel extract, 69 ml papaya leaf extract and 150 ml soap base were prepared.
Mixing	The specified amounts of pomelo peel extract and papaya leaf extract for each treatment were gradually added to the soap base and mixed thoroughly until uniform and homogeneous liquid hand soap was obtained.
Bottling and Labeling	The final liquid hand soap was placed in clean, airtight pump containers and properly labeled.

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1. Weighing of ingredients in preparing Potassium Hydroxide (KOH)



2. Dissolving of Potassium Hydroxide (KOH) to Distilled Water



3. Cooking the Mixture



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4. Diluting the Soap Paste



5. Picking/ Harvesting of Pomelo Fruits and Papaya Leaves



6. Washing and Slicing Pomelo Peels and Papaya Leaves



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7. Extracting Pomelo Peels and Papaya Leaves



8. Measuring of extracts and soap base



9. Mixing of extracts and soap base



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10. Bottling and labeling of the finished product



Table 5: Antibacterial Analysis of Pomelo and Papaya Antibacterial Liquid Hand Soap

Sample Number	Sample Type	Test Organism: E.Coli Average Zone of Inhibition obtained in mm Size of Disc : 6 cm	ANALYSIS
T1		19.0 mm	Active
T2		18.0 mm	Active
T3		17 mm	Active

The table 5 shows the results of antibacterial analysis of Pomelo and Papaya Antibacterial Liquid Hand Soap. The results of the microbial screening revealed that all three liquid soap formulations, T1, T2, and T3, exhibited measurable inhibitory activity against *Escherichia coli* (*E. coli*), as evidenced by the zones of inhibition surrounding the paper discs. The inhibition zones ranged from 17 mm to 19 mm, classifying all formulations within the “active” antimicrobial category (Saxena et al., 2020).

The largest zone of inhibition was observed in T1 (19.0mm), indicating that this formulation has the strongest antibacterial effect among the three samples tested. This suggests that the components or concentration of active compounds present in T1—possibly higher levels of bioactive phytochemicals from pomelo or papaya extract—are more effective in suppressing the growth of *E. coli*. The formation of a clear zone around the discs indicates that the liquid soap samples contain antimicrobial compounds capable of diffusing through the medium and inhibiting bacterial growth. Since *E. coli* is a common indicator organism for gram-negative bacteria, these findings suggest that the pomelo and papaya liquid soap formulations have the potential to act as natural antibacterial agents, particularly for sanitizing or personal hygiene applications (Rahman et al., 2018). The antibacterial effect is likely due to the presence of phytochemicals such as alkaloids, phenolics, flavonoids, and essential oils, many of which have been reported to disrupt bacterial cell membranes, inhibit enzyme activity, and interfere with protein synthesis, thereby preventing bacterial growth.

The gradual decrease in inhibition from T1 (19 mm) to T3 (17 mm) may be due to differences in concentration of active extract, ratio of pomelo to papaya, presence or absence of supporting natural antimicrobials (essential oils, acids, etc.), pH or surfactant formulation of each liquid soap

Even at 17 mm, T3 still demonstrates meaningful antibacterial activity, which confirms that all formulations tested are microbiologically active.

The results support the use of pomelo and papaya extracts as effective natural antibacterial agents, particularly against gram-negative bacteria like *E. coli*. This provides scientific evidence that the liquid soap formulations have functional hygienic properties, making them potentially useful for personal care products, natural disinfectant or antibacterial soap lines and complementary or alternative natural hygiene solutions (Hassan & Lim, 2021).

Table 6 General Level of Acceptability of the Developed Pomelo and Papaya Antibacterial Liquid Soap Along Three Treatments

Indicator	Mean	Sd	Description
T1 (70 ml Pomelo Peel Extract:30 ml Papaya Leaf Extract)			
Cleansing	4.87	0.35	Highly Acceptable
Color	4.67	0.71	Highly Acceptable
Foaming	4.57	0.68	Highly Acceptable
Fragrance	4.60	0.86	Highly Acceptable

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<i>Lathering</i>	4.80	0.48	Highly Acceptable
<i>Moisturizing</i>	4.87	0.35	Highly Acceptable
Overall Mean	4.73	0.43	Highly Acceptable
T2 (50 ml Pomelo Peel Extract:50 ml Papaya Leaf Extract)			
<i>Cleansing</i>	4.90	0.31	Highly Acceptable
<i>Color</i>	4.63	0.85	Highly Acceptable
<i>Foaming</i>	4.57	0.68	Highly Acceptable
<i>Fragrance</i>	4.47	0.86	Highly Acceptable
<i>Lathering</i>	4.70	0.47	Highly Acceptable
<i>Moisturizing</i>	4.67	0.48	Highly Acceptable
Overall Mean	4.66	0.36	Highly Acceptable
T2 (30 ml Pomelo Peel extract:70 ml Papaya Leaf Extract)			
<i>Cleansing</i>	4.93	0.25	Highly Acceptable
<i>Color</i>	4.73	0.78	Highly Acceptable
<i>Foaming</i>	4.87	0.35	Highly Acceptable
<i>Fragrance</i>	4.70	0.47	Highly Acceptable
<i>Lathering</i>	4.73	0.45	Highly Acceptable
<i>Moisturizing</i>	4.80	0.41	Highly Acceptable
Overall Mean	4.79	0.30	Highly Acceptable

Across the three treatments, all indicators yielded mean scores ranging from 4.47 to 4.93, indicating that the developed pomelo–papaya liquid soap was consistently rated as Highly Acceptable. The highest mean rating was recorded in T3 (30 ml Pomelo Peel Extract: 70 ml Papaya Leaf Extract) for Cleansing with mean score = 4.93, and a standard deviation = 0.25 and foaming with mean = 4.87, Sd = 0.35. These high means, coupled with low standard deviations, imply that respondents not only perceived T3 as very effective in cleansing and producing foam but also demonstrated strong agreement, suggesting a uniform positive response.

On the other hand, the lowest mean rating was observed in T2 for Fragrance with mean = 4.47, Sd = 0.86. While still “Highly Acceptable,” the relatively lower score and the highest standard deviation among all indicators show that respondents had more varied perceptions of T2’s fragrance quality—indicating less consistency and possibly a less appealing scent profile for some users. When comparing overall means, T3 again ranked highest as shown by the mean = 4.79, Sd = 0.30, followed by T1 with mean = 4.73 and Sd = 0.43, and T2 with mean = 4.66, Sd = 0.36. T3’s combination of the highest overall acceptability and the lowest overall standard deviation suggests that it was the most favorably and consistently rated formulation. Meanwhile, T2’s slightly lower overall mean and moderate variability indicate that although acceptable, it may require refinement, particularly in attributes such as fragrance and color where variability was notable.

In general, the level of acceptability of the developed pomelo and papaya liquid soap across the three treatments is highly favorable, as reflected by consistently high mean ratings. Among the formulations, T3 emerged as the most acceptable and most consistently rated, showing that a higher proportion of papaya leaf extract enhances user satisfaction across various qualities. The analysis of standard deviations further supports that respondents were most uniform in their positive evaluation of T3, whereas T2 showed the greatest variability, particularly in fragrance. Overall, all treatments demonstrate strong potential for consumer acceptance, with T3 standing out as the optimal formulation.

Table 7 Level of Acceptability of the Developed Pomelo and Papaya Liquid Hand Soap Along Three Treatments as Perceived by the Different Groups of Respondents

Indicators T1	Teenagers Mean	Respondents Description	Adult s Mean	Description	Beauty Experts Mean	Description
Cleansing	4.90	Highly Acceptable	4.90	Highly Acceptable	4.80	Highly Acceptable
Color	4.70	Highly Acceptable	5.00	Highly Acceptable	4.30	Highly Acceptable
Foaming	4.70	Highly Acceptable	4.60	Highly Acceptable	4.40	Highly Acceptable
Fragrance	4.80	Highly Acceptable	4.70	Highly Acceptable	4.30	Highly Acceptable
Lathering	5.00	Highly Acceptable	4.80	Highly Acceptable	4.60	Highly Acceptable
Moisturizing	4.90	Highly Acceptable	4.80	Highly Acceptable	4.90	Highly Acceptable

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Overall Mean	4.83	Highly Acceptable	4.80	Highly Acceptable	4.55	Highly Acceptable
T1	Teenagers Mean	Description	Adult s Mean	Description	Beauty Experts Mean	Description
Cleansing	5.00	Highly Acceptable	4.90	Highly Acceptable	4.8	Highly Acceptable
Color	4.70	Highly Acceptable	5.00	Highly Acceptable	4.2	Highly Acceptable
Foaming	4.60	Highly Acceptable	4.60	Highly Acceptable	4.5	Highly Acceptable
Fragrance	4.50	Highly Acceptable	4.70	Highly Acceptable	4.2	Highly Acceptable
Lathering	5.00	Highly Acceptable	4.70	Highly Acceptable	4.40	Highly Acceptable
Moisturizing	4.80	Highly Acceptable	4.40	Highly Acceptable	4.80	Highly Acceptable
Overall Mean	4.77	Highly Acceptable	4.72	Highly Acceptable	4.48	Highly Acceptable
T1	Teenagers Mean	Description	Adult s Mean	Description	Beauty Experts Mean	Description
Cleansing	5.00	Highly Acceptable	5.00	Highly Acceptable	4.80	Highly Acceptable
Color	4.90	Highly Acceptable	5.00	Highly Acceptable	4.30	Highly Acceptable
Foaming	4.90	Highly Acceptable	4.90	Highly Acceptable	4.80	Highly Acceptable
Fragrance	4.60	Highly Acceptable	4.90	Highly Acceptable	4.60	Highly Acceptable
Lathering	5.00	Highly Acceptable	4.90	Highly Acceptable	4.30	Highly Acceptable
Moisturizing	4.90	Highly Acceptable	4.90	Highly Acceptable	4.60	Highly Acceptable
Overall Mean	4.88	Highly Acceptable	4.93	Highly Acceptable	4.57	Highly Acceptable

Across the three treatments, all indicators yielded mean scores ranging from 4.47 to 4.93, indicating that the developed pomelo–papaya liquid soap was consistently rated as highly acceptable. The highest mean rating was recorded in T3 (30 ml Pomelo Peel Extract: 70 ml Papaya Leaf Extract) for cleansing with a mean score of 4.93 and standard deviation of 0.25, and for foaming with a mean of 4.87 and standard deviation of 0.35. These high mean scores, coupled with low standard deviations, imply that respondents perceived T3 as very effective in cleansing and producing foam, with strong agreement among evaluators, suggesting a uniform positive response (Ismail & Sulaiman, 2020).

On the other hand, the lowest mean rating was observed in T2 for fragrance with a mean of 4.47 and standard deviation of 0.86. While still highly acceptable, the relatively lower score and highest standard deviation among all indicators indicate more varied perceptions of T2's fragrance quality, suggesting less consistency and potentially a less appealing scent profile for some users (Rahman, Ahmad, & Noor, 2019).

When comparing overall means, T3 again ranked highest with a mean of 4.79 and standard deviation of 0.30, followed by T1 with a mean of 4.73 and standard deviation of 0.43, and T2 with a mean of 4.66 and standard deviation of 0.36. T3's combination of the highest overall acceptability and lowest standard deviation indicates it was the most favorably and consistently rated formulation, while T2's slightly lower overall mean and moderate variability suggest that, although acceptable, it may benefit from minor refinements, particularly in fragrance and color where variability was notable (Hassan & Lim, 2021).

In general, the level of acceptability of the developed pomelo and papaya liquid soap across the three treatments is highly favorable, reflecting consistently high mean ratings. Among the formulations, T3 emerged as the most acceptable and consistently rated, demonstrating that a higher proportion of papaya leaf extract enhances user satisfaction across multiple quality attributes. The analysis of standard deviations further supports that respondents were most uniform in their positive evaluation of T3, whereas T2 showed the greatest variability, particularly in fragrance. Overall, all treatments demonstrate strong potential for consumer acceptance, with T3 standing out as the optimal formulation for market and practical use.

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Table 8 Comparison on the General Level of Acceptability of the Developed Pomelo and Papaya Liquid Hand Soap Along Three Treatments as Perceived by the Different Groups of Respondents

Treatments	Indicators	F-Value	R-value	Decision	Remarks
T1	Cleansing	0.2647	0.7694	Accept H_0	Not Significant
	Color	2.7295	0.0832	Accept H_0	Not Significant
	Foaming	0.4884	0.6189	Accept H_0	Not Significant
	Fragrance	0.9545	0.3976	Accept H_0	Not Significant
	Lathering	1.8000	0.1846	Accept H_0	Not Significant
	Moisturizing	0.2647	0.7694	Accept H_0	Not Significant
T2	Cleansing	1.0800	0.3538	Accept H_0	Not Significant
	Color	2.4925	0.1016	Accept H_0	Not Significant
	Foaming	0.0677	0.9347	Accept H_0	Not Significant
	Fragrance	0.8465	0.4400	Accept H_0	Not Significant
	Lathering	5.4000	0.0106	Reject H_0	Difference is Significant
	Moisturizing	2.5714	0.0950	Accept H_0	Not Significant
T3	Cleansing	2.2500	0.1248	Accept H_0	Not Significant
	Color	2.5800	0.0943	Accept H_0	Not Significant
	Foaming	0.2647	0.7694	Accept H_0	Not Significant
	Fragrance	1.4211	0.2589	Accept H_0	Not Significant
	Lathering	12.9000	0.0001	Reject H_0	Difference is Significant
	Moisturizing	1.9286	0.1649	Accept H_0	Not Significant

The comparison of the general level of acceptability of the pomelo and papaya liquid hand soap across the three treatments indicates that, for most sensory indicators, the perceptions of teenagers, adults, and beauty experts do not significantly differ. In Treatment 1, all indicators, including cleansing, color, foaming, fragrance, lathering, and moisturizing, showed non-significant results, as evidenced by high p-values. This demonstrates that respondents across different age groups and expertise levels shared similar evaluations of the product, reflecting a consistently high acceptability regardless of user background (Ismail & Sulaiman, 2020).

A similar pattern was observed in Treatment 2, where all indicators except lathering yielded nonsignificant differences. Cleansing, color, foaming, fragrance, and moisturizing had p-values above the 0.05 threshold, confirming uniform assessments among the respondent groups. However, lathering displayed a significant difference with a p-value of 0.0106, suggesting that respondents varied in their perception of the soap's lathering quality, with beauty experts likely applying more technical and professional standards compared to teenagers and adults (Rahman, Ahmad, & Noor, 2019).

In Treatment 3, most indicators again showed non-significant results, indicating consistent perceptions of cleansing, color, foaming, fragrance, and moisturizing among all groups. The only exception was lathering, which had a highly significant p-value of 0.0001. This indicates that respondents differed notably in judging the lathering quality of the third formulation, with beauty experts evaluating this attribute more critically (Hassan & Lim, 2021).

Overall, these findings suggest that the majority of acceptability indicators were consistently rated across teenagers, adults, and beauty experts, confirming that the developed pomelo and papaya liquid hand soap enjoys stable and favorable acceptance among diverse users. The lathering attribute, however, was more susceptible to variation in perception, particularly from trained evaluators. Despite these isolated differences, all treatments remained highly acceptable, affirming the product's broad consumer appeal and its potential suitability for a wide range of users.

Table 9. Post-Hoc Analysis of the General Level of Acceptability of the Developed Pomelo and Papaya Liquid Hand Soap Along Three Treatments as Perceived by the Different Groups of Respondents

Indicators	(I) Groups	(J) Groups	Mean Difference (I – J)	r-value
T2 (Lathering)	Teenagers	Adults	0.30	0.2454
		Beauty Experts	0.60	0.0077
	Adults	Beauty Experts	0.30	0.2454
T3 (Lathering)	Teenagers	Adults	0.10	0.7822
		Beauty Experts	0.70	0.0002
	Adults	Beauty Experts	0.60	0.0012

The post-hoc analysis for the lathering attribute in Treatments 2 and 3 reveals the specific respondent groups where significant differences in perception occur.

In Treatment 2, the comparison between teenagers and adults shows no significant difference, as indicated by the p-value of 0.2454, suggesting that both groups shared similar perceptions of the soap's lathering quality. However, the comparison between teenagers

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and beauty experts shows a mean difference of 0.60 with a p-value of 0.0077, indicating a statistically significant difference. This implies that beauty experts rated the lathering performance of Treatment 2 noticeably lower than teenagers, reflecting a more critical assessment likely due to their professional experience and higher expectations for product performance. The comparison between adults and beauty experts, with a mean difference of 0.30 and a p-value of 0.2454, shows no statistically significant difference, though a slight numerical gap is observed, suggesting some minor divergence in professional evaluation (Rahman, Ahmad, & Noor, 2019). In Treatment 3, teenagers and adults again demonstrate no significant difference in their ratings, supported by the high p-value of 0.7822, reflecting consistent perceptions among general consumers. The most notable differences, however, appear between teenagers and beauty experts, with a mean difference of 0.70 and a highly significant p-value of 0.0002. Adults and beauty experts also differ significantly, with a mean difference of 0.60 and a p-value of 0.0012. These findings indicate that for the third formulation, beauty experts consistently rated the lathering attribute lower than both teenagers and adults, demonstrating a stricter evaluation standard regarding foam quality and overall performance (Hassan & Lim, 2021).

Overall, the pattern across both treatments is consistent: teenagers and adults generally align in their evaluations, whereas beauty experts tend to provide more critical ratings of lathering. This trend suggests that while the developed pomelo and papaya liquid hand soap performs well among general consumers, professional evaluators identify areas where formulation refinements could enhance lathering quality. Despite these observed differences, all ratings remain within acceptable levels, indicating that the product is broadly suitable for general use while offering actionable insights for potential improvement based on expert feedback (Ismail & Sulaiman, 2020).

Table 10. Summary of Cost-Benefit Analysis of Pomelo and Papaya Antibacterial Liquid Hand Soap

Ingredients	Measurement	Treatment 1	Treatment 2	Treatment 3
Potassium Hydroxide (KOH)	25 g	₱ 5.00	₱ 5.00	₱ 5.00
Virgin Coconut Oil (VCO)	109 ml	₱ 44.50	₱ 44.50	₱ 44.50
Distilled water	100 ml	₱1.30	₱1.30	₱1.30
Pomelo peel extract	66ml/47ml/27ml	₱ 0	₱ 0	₱ 0
Papaya leaf extract	30ml/49ml/69ml	₱ 0	₱ 0	₱ 0
Additional Expenses				
Pump Bottle	250 ml	₱ 25.00	₱ 25.00	₱ 25.00
Label		₱ 1.00	₱ 1.00	₱ 1.00
Other Operational Expenses				
Electricity		₱ 5.00	₱ 5.00	₱ 5.00
LPG		₱ 5.00	₱ 5.00	₱ 5.00
TOTAL		₱ 86.80	₱ 86.80	₱ 86.80

Note: 250 ml per treatment

Table 10 presents the breakdown of ingredients, materials, and operational expenses involved in the production of the pomelo and papaya liquid hand soap across the three treatments. The table shows that the total production cost per treatment amounted to ₱86.80 for a 250 mL bottle, with no variation among the treatments despite differences in the volume ratios of pomelo peel extract and papaya leaf extract.

The costs of the core soap base ingredients—potassium hydroxide (KOH), virgin coconut oil (VCO), and distilled water—remained constant across all treatments. Potassium hydroxide, required for the saponification process, contributed ₱5.00 per treatment, while virgin coconut oil, the primary oil source in the formulation, accounted for the largest material cost at ₱44.50. Distilled water, used in both extraction and soap formulation, had a minimal cost of ₱1.30. These findings indicate that the base formulation costs are stable and unaffected by the treatment variations.

Notably, the pomelo peel extract and papaya leaf extract incurred no monetary cost across all treatments, as these plant materials were locally sourced and readily available. This significantly contributed to the overall affordability of the product and highlights the advantage of utilizing agricultural byproducts and indigenous plant resources in liquid hand soap production. Although the extract volumes differed among treatments, these variations did not influence the total production cost, demonstrating that changing extract ratios does not increase material expenses.

Additional expenses such as packaging and operational costs were also consistent across treatments. The 250 mL pump bottle constituted a significant portion of the total cost at ₱25.00, while labeling added ₱1.00. Operational costs, including electricity and liquefied petroleum gas (LPG), were equally distributed at ₱5.00 each. These expenses reflect practical considerations necessary for product preparation and bottling.

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Overall, Table 10 indicates that all three treatments required the same total production cost, suggesting that the formulation ratios of pomelo peel extract and papaya leaf extract do not affect the economic cost of production. This cost uniformity supports the feasibility of producing the liquid hand soap in different formulations without additional financial burden. The results further emphasize the potential of the product as a cost effective, sustainable, and viable option for small scale or community-based production.

Table 11. Summary Computation of Return on Investment in Pomelo and Papaya Antibacterial Liquid Hand Soap

Particulars	Treatment 1	Treatment 2	Treatment 3
Total Production Cost	₱86.80	₱86.80	₱86.80
Unit Cost (per 250 mL bottle)	₱86.80	₱86.80	₱86.80
Markup (50% of Unit Cost)	₱43.40	₱43.40	₱43.40
Selling Price in the Market	₱130.20	₱130.20	₱130.20
Total Sales (per 250 mL bottle)	₱130.20	₱130.20	₱130.20
Income (Total Sales – Total Production Cost)	₱43.40	₱43.40	₱43.40
ROI (%)	50%	50%	50%

Table 11 presents the summary computation of the return on investment (ROI) for the pomelo and papaya antibacterial liquid hand soap across the three treatments. The results indicate that the total production cost for each treatment was ₱86.80 per 250 mL bottle, resulting in the same unit cost for all formulations. This consistency reflects the uniformity of ingredient costs and operational expenses, regardless of the varying proportions of pomelo peel extract and papaya leaf extract used in the treatments.

A 50% markup was applied to the unit cost, amounting to ₱43.40, to determine the selling price in the market, which was computed as ₱130.20 per bottle. The application of a uniform markup across treatments resulted in identical total sales values of ₱130.20 per 250 mL bottle. This pricing strategy demonstrates that the product can be competitively priced while still accounting for production expenses and reasonable profit.

The computed income for each treatment was ₱43.40, derived from the difference between total sales and total production cost. Consequently, the return on investment (ROI) for all three treatments was calculated at 50%, indicating that for every peso invested in production, fifty centavos were gained as profit. The identical ROI values across treatments suggest that modifications in extract ratios do not affect the economic profitability of the product.

Overall, the results presented in Table 11 show that the pomelo and papaya antibacterial liquid hand soap is economically viable and profitable under smallscale production conditions. The consistent ROI across all treatments highlights the product's potential suitability for entrepreneurial ventures and communitybased enterprises, as it offers a favorable balance between affordability, sustainability, and profitability without increasing production costs.

5. SUMMARY OF FINDINGS, CONCLUSION, & RECOMMENDATIONS

5.1 Summary of Findings

Based on the data presented, the researchers arrived at the following findings:

- The study successfully formulated a natural antibacterial liquid hand soap using pomelo peel and papaya leaf extracts. The soap preparation followed a systematic process, beginning with the preparation of the KOH – based soap, extraction of plant materials, mixing with the soap base, and proper bottling and labeling. These procedures ensured a stable and high-quality product while maximizing the extraction of bioactive compounds.
- All three formulations (T1, T2, T3) exhibited notable antibacterial activity against *Escherichia coli*, with inhibition zones ranging from 17 mm to 19 mm. T1 showed the highest antibacterial effect; however, all formulations were active, validating the potential of pomelo and papaya extracts as natural antibacterial agents suitable for personal hygiene.
- Consumer evaluation revealed high acceptability across all attributes, including cleansing, color, foaming, fragrance, lathering, and moisturizing. Among the three formulations, T3 (27 ml Pomelo Peel Extract: 69 ml Papaya Leaf Extract) received the highest overall acceptability, indicating that a higher proportion of papaya leaf extract enhances user satisfaction. Teenagers and adults rated the product slightly higher than beauty experts, reflecting a more critical assessment from professionals. Nevertheless, all ratings were within the “Highly Acceptable” range, confirming broad consumer approval.
- All three respondent groups rated the three treatments as highly acceptable. Teenagers and adults generally provided higher acceptability scores, while beauty care teachers/ salon employees gave slightly lower – but still highly acceptable – ratings, reflecting

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more professional and critical evaluation. Treatment 3 consistently obtained the highest overall mean ratings across all respondent groups.

e. Statistical analysis using One-Way ANOVA revealed no significant difference in the general level of acceptability of the three treatments when evaluated by teenagers, adults, and beauty care teachers/ salon employees.

f. The cost-benefit analysis revealed that the production of pomelo and papaya antibacterial liquid hand soap had a uniform total cost of ₱86.80 per 250 mL bottle across all three treatments, indicating that variations in extract ratios did not affect production expenses. The use of locally sourced pomelo peel and papaya leaf extracts resulted in zero raw material cost for active ingredients, significantly lowering overall expenses. Packaging and operational costs, particularly the pump bottle, comprised a substantial portion of production cost. With a selling price of ₱130.20 per bottle and an income of ₱43.40, all treatments generated a consistent return on investment (ROI) of 50%, demonstrating equal profitability and strong marketability potential.

Overall, the study highlights that the formulated soap combines antibacterial efficacy, high consumer acceptability, and financial feasibility, making it a viable natural alternative to commercial antibacterial soaps.

5.2 Conclusion

Based on the findings, the researcher reached the following conclusions:

a. The Pomelo and Papaya Antibacterial Liquid Hand Soap could be successfully formulated into a stable, safe, and high-quality product using practical and accessible methods.

b. All three formulations demonstrated antibacterial activity against *E. coli*, confirming the effectiveness of pomelo peel and papaya leaf extracts as natural antibacterial agents.

c.T3 (27 ml Pomelo Peel Extract: 69 ml Papaya Leaf Extract) emerged as the most preferred formulation, receiving the highest overall acceptability across respondents, indicating its superior sensory and functional qualities.

d. While beauty experts provided slightly lower evaluations for fragrance, color, and lathering, all formulations remained highly acceptable, suggesting minor improvements could enhance professional appeal.

e. There is no significant difference in the acceptability ratings among the different respondent groups. This indicates that the soap's quality and performance are consistently perceived, regardless of age group or professional background.

f. the developed pomelo and papaya antibacterial liquid hand soap is economically viable, cost-effective, and profitable regardless of the extract formulation used. The constant production cost and consistent 50% ROI across all treatments indicate that the product can be produced and marketed without financial disadvantage. The utilization of natural, locally available plant extracts further enhances the product's affordability and sustainability, supporting its potential for smallscale, communitybased, or entrepreneurial production.

5.3 Recommendations

Based on the findings of this study, the following recommendations were proposed:

a. For product development and utilization in health services, it is recommended that Treatment 3 (27 mL pomelo peel extract and 69 mL papaya leaf extract) be adopted as the preferred formulation due to its superior acceptability and effective antibacterial properties. This formulation may be considered for use in health centers, clinics, schools, and sanitation programs as an alternative hand hygiene product, particularly in communitybased health initiatives. Minor improvements in fragrance, color, and lathering may further enhance user acceptance and support its safe and regular use in hygiene promotion and infection prevention activities.

b. For future research and safety assurance, it is suggested that further studies evaluate the shelf life, formulation stability, and longterm antibacterial efficacy of the liquid hand soap to ensure product safety and suitability for wider distribution, including in health service settings. Additional research may also explore the soap's effectiveness against a broader range of microorganisms and assess the incorporation of other natural additives, such as essential oils, to enhance antimicrobial activity while maintaining safety standards relevant to public health use.

c. For commercialization and marketability, small-scale to community level production is highly recommended, as the study demonstrates strong economic viability, low production cost, and a consistent return on investment. The product shows potential for local commercialization and entrepreneurship, particularly for cooperatives, livelihood programs, and small businesses. Improved packaging design and labeling should be considered to ensure durability, consumer appeal, and compliance with product safety and marketing standards. Marketing strategies may emphasize the soap's natural ingredients, costeffectiveness, antibacterial function, and ecofriendly origin, which support consumer acceptability and potential market demand.

d. For community, educational, and public health application, the adoption of plant based antibacterial soaps should be encouraged as part of hygiene education, sanitation campaigns, and community health improvement programs. Collaboration with local health services, schools, and local government units may help promote awareness of safe hand hygiene practices while supporting sustainable product use and local economic development. This approach highlights the study's contribution not only to product development but also to health promotion, sanitation awareness, and community empowerment.

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