EVALUATION OF PHYSICOCHEMICAL, ANTIBACTERIAL, SENSORY PROPERTIES AND SHELF LIFE OF A BATH SOAP CONTAINING CAMEL MILK CREAM

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DECLARATION

This thesis is my original work and has not been presented for the award of a degree in any other institution.

SC406/202294/21

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DEDICATION

This work is dedicated to my beloved parents, Jesica Alango and Joseph Alango, whose constant support and guidance have fostered in me a profound love for education. I also dedicate it to my wonderful wife, Nancy Achieng, and my dear daughters, Sandy Clara and Wendy Marion, for their unwavering encouragement and inspiration. Above all, I give glory to God.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS

ASAL	Arid and Semi-Arid Lands
MMT	Million Metric Tons
SDGs	Sustainable Development Goals
AHA	Alpha Hydroxyl Acid
WHO	World Health Organization
MCT-7	Michigan Cancer Fundations-7
TFM	Total Fatty Matter

ABSTRACT

The growing interest in therapeutic and natural personal care products has fuelled the study for alternative to synthetic ingredients. Camel milk being rich in proteins, vitamins, and antimicrobial properties, is a promising active ingredient for skin care formulations. This study, therefore, explored the possibility of using camel milk cream in bath soap formulation and analysed its physicochemical properties, antibacterial activity and sensory acceptability. Bath soaps were produced using the cold saponification process using camel milk cream, palm oil, and coconut oil as primary ingredients. Fresh camel milk and cream were subjected to compositional and quality analyses, including density (Lactometer), fat content (Gerber method), and protein content (Kjeldahl method). The saponification reaction and resultant soap formulations were further analysed using Fourier Transform Infrared Spectroscopy (FTIR) to monitor functional group changes and confirm reaction completion. The formulated soaps were characterized for physicochemical properties such as pH (multiparameter pH meter), total fatty matter (gravimetric method), moisture content (oven-drying at 110 °C), foam stability (cylinder shake test), hardness (cone penetrometer) and alkali content (acid–base titration). Shelf-life was evaluated over 8 weeks by monitoring pH, alkali content, and total fatty matter. Antibacterial activity against *S. aureus* and *E. coli* was determined using the agar well diffusion method, with inhibition zones analysed by Duncan's multiple range Test ($p < 0.05$). Sensory evaluation was performed with 20 untrained panellists aged 18 – 37 years under controlled conditions to assess formability, skin feel, moisturizing, odour, texture, hardness and overall acceptability. The results were as follows; density of 1.031 g/cm^3, fat content of 43.33 ± 0.58%, and protein content of 1.94 ± 0.07%, respectively. FTIR confirmed complete saponification by the loss of ester carbonyl (C=O) at 1742 cm^{-1} and appearance of carboxylate (COO^-) at 1554 and 1408 cm^{-1}, while amide bands at 1649 and 1465 cm^{-1} indicated the presence of proteins from camel milk cream. The formulated soaps were subjected to determination of some important physicochemical parameters such as pH (10.17 - 11.51), total fatty matter (45.19 - 66.43%), moisture content (21.06 - 33.40%), foam stability (0.33 - 1.37 cm), hardness (0.281 - 0.639 kPa), alkali content. Over 8 weeks, the soaps maintained acceptable quality, with moisture decreasing slightly. Soap samples containing comparatively more concentrations of camel milk cream were found to have a significantly higher ($p < 0.05$) antibacterial activity. The sensory evaluation indicated high consumer acceptability, with positive feedback on the soap's skin-smoothing and moisturizing effects. All the parameters analysed were compared with commercial soaps such as Imperial leather. Remarkably, the soap formulated with 20% coconut oil and 20% camel milk cream showed a balanced physicochemical properties and antibacterial activities comparable to that of Dettol. These findings suggest that camel milk cream can serve as an effective natural alternative to synthetic antibacterial agents used in commercial soaps.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Cosmetics play a significant role in enhancing the human body's appearance, beauty, boosting their confidence and expressing their individuality (Kaushik *et al*., 2019). Cosmetics therefore become a tool for self-expression, providing a way for individuals to connect with their cultural heritage and feel a sense of belonging (Sena, 2025). With advancements in cosmetic science, innovative products that offer better performance and improved compatibility with different skin types have been developed (Dreno *et al*., 2014). Cosmetics are broadly categorized into three groups depending on the purpose: haircare, skincare, and personal care. Haircare cosmetics such as shampoos are devoted to enhancing hair appearance by cleaning hair and scalp (Sonawane *et al*., 2021). On the other hand, skincare and personal care cosmetics are used to exfoliate dead cells on the skin and to clean the body respectively (Behalpade & Gajbhiye, 2022).

Cosmetics are either formulated from natural products or synthesized from chemical compounds (Schneider *et al*., 2001). Synthetic cosmetic formulations are found to contain colorants which are mostly aromatic ring and azo compounds that consequently cause side effects such as allergies and asthma to susceptible consumers (Oymak *et al*., 2019). Additionally, in the European Union, the use of parabens such as benzyl, isobutyl, isopropyl, and phenyl parabens as preservatives in cosmetic products is prohibited under Commission Regulation (EU) No 358/2014 (Lecce *et al*., 2016). A clinical study on the exposure of parabens and breast cancer showed that paraben increases the chances of breast cancer since paraben is hydrolyzed to p-hydroxybenzoic acid by esterase (Hager *et al*., 2022). Moreover, some synthetic cosmetics are illegally made up of heavy metals such as lead and cadmium to enhance colour due to their ability to split their d-orbitals allowing electrons to transition from low to high energy orbitals (Raza *et al*., 2022). These heavy metals expose consumers to disorders like cancer (Jaishankar *et al*., 2014).

On the other hand, the growing interest in natural and sustainable cosmetic ingredients is attributed to the absence of any side effects to the consumers (Suphasomboon & Vassanadumrongdee, 2022). Natural products have emerged as the finest substitutes for synthetic ingredients in cosmetic formulations following their efficiency and safety characteristics and consequently, there is an increased demand for natural cosmetics (Ghazali *et al*., 2017). For instance, avocado oil, neem and aloe vera have been widely used in formulations of soaps and shampoos due to their antifungal and antioxidant properties (Chanchal & Swarnlata, 2008).

Recently, milk has become a good ingredient for naturally made skincare cosmetics as it is loaded with casein and lactoferrin proteins which have anti-fungal and anti-cancer properties (Kazimierska & Kalinowska, 2021). Dairy milk is a better ingredient for skincare cosmetics as it is reported to be a rich source of lactic acid for which *in vitro* experiments have shown that it exfoliates dead cells from the skin thereby promoting growth of new cells (Bhardwaj *et al.*, 2021; Ishikawa *et al.*, 2021). Notably, in Indonesia, high quality cosmeceuticals for skin and haircare are made from goat milk (Sumarmono, 2022). Lactic acid contained in goat milk moisturizes and soothes the skin in addition to shedding off the dead cells and promoting new cell growth. Similarly, Murti *et al.,* (2024), reported goat milk cream-based bar soap as a mild soap for human skin use.

Camel milk, the main source of livelihood for arid and semi-arid communities especially herders on long grazing periods (Faye *et al*., 2014), is reported as a rich source of α-hydroxyl acids (Mahmoud et al., 2021), which offer solution to skin diseases such as dermatitis and acne.

The incorporation of camel milk cream into bath soap formulations represents a promising approach to harnessing natural product chemistry for skin health. However, its application in bath soap production remains insufficiently investigated. This study therefore aimed to incorporate camel milk cream into bath soap and evaluate its physicochemical properties, shelf life and potential to address skin concerns such as bacterial infection, irritation, and moisturizing effect.

1.2 Problem Statement

Chemically synthesized cosmeceuticals have been associated with adverse health effects, including skin cancer, as well as toxicological impacts (A. M. Alnuqaydan, 2024). These concerns have shifted consumer demand toward natural cosmetic alternatives (Acharya & Sunayan, 2024). Despite the growing interest in natural cosmetic products, there is limited scientific study on the formulation and physicochemical properties of bath soaps enriched with camel milk cream (Mehta & Agrawal, 2020). Camel milk contains bioactive compounds, including proteins, lipids, and α-hydroxy acids, which are reported to offer skin benefits such as moisturization, exfoliation, and antimicrobial activity (Yaseen & Hanee, 2019). However, the physicochemical stability, antibacterial efficacy, sensory attributes, and shelf life of such formulations have not been adequately characterized compared to commercial soaps.

1.3 Justification

Compared to other ruminants' milk, researchers have found that camel milk is a rich source of bioactive compounds such as casein, lactoferrin, immunoglobulins, lysozyme, and vitamins. These compounds have health benefits, including antimicrobial, anti-inflammatory, and moisturizing properties (Mohammadabadi, 2020). Therefore, harnessing these health-promoting components for skincare toiletries may present a novel solution for addressing various dermatological conditions and maintaining skin health. This will in turn contribute to the achievement of Sustainable Development Goals (SDG) 3: “Good Health and Well-being”.

Kenya is ranked globally as one of the leading producers of camel milk as it records approximately 1.165 million metric tonnes of camel milk by volume every year *(Oselu et al.*, 2022). However, despite Kenya being on the global map as a leading producer of camel milk, the availability of camel milk derived cosmetics products remains limited in the market due to unawareness of its cosmetic use and market value. Therefore, incorporation of camel milk cream in cosmeceuticals would present an opportunity for economic development as it would create a source of income to the ASAL communities. Supporting camel milk value chains especially though the use of camel milk in cosmetic formulations, can increase rural incomes, empower pastoralist communities, and expand market opportunities (Machan *et al.*, 2022).

Food and Agriculture Organization statistics (FAOSTAT, 2025) shows that Kenya is among the countries with the largest population of camel in East Africa. In addition, since many people do not consume camel milk, its utilization in skincare and toiletries would not rather pose a threat to food security but rather boosts the commercial value of camel products (Oselu *et al*., 2022). Therefore, the production of camel milk cream-based soap would expand the market demand for camel milk and consequently open job opportunities for the ASAL communities, thereby improving their living standards and hence contributing to the full realization of the first Sustainable Development Goals (SDGs); “No poverty”.

1.4 Research Objectives

1.4.1 General Objectives

To evaluate the physicochemical, antibacterial and sensory properties of a bath soap containing camel milk cream.

1.4.2 Specific Objectives

i. To analyze the physicochemical properties of the bath soap containing camel milk cream.

ii. To conduct antibacterial activity for the formulated bath soap and compare its efficacy with that of commercial antibacterial soaps.

iii. To conduct sensory evaluation tests of the formulated bath soap.

1.5 Research Questions

i. What are the specific physicochemical properties of soap formulated with camel milk cream?

ii. What are the antibacterial properties of the formulated bath soap?

iii. What is the sensory acceptability of the formulated bath soap based on consumer evaluation of its lather, texture, fragrance, and skin feel?

CHAPTER TWO: LITERATURE REVIEW

Potential application of camel milk as a therapeutic ingredient in bath soaps and shampoos

Abstract

The increasing worldwide market for natural-ingredient-based cosmetics is fuelled by the awareness of the dangers of synthetic cosmetics and benefits of natural-based cosmetics on the skincare and management of skin disorders. Besides natural formulated cosmetics being biodegradable, they also contain ingredients which are chemically beneficial to human skin. Milk-based cosmetics are very promising since milk is rich in essential components such as lactoferrins, vitamins and lactic acids which have shown therapeutic properties against disorders like skin cancer, acne scars and dandruff. One of the milks that is very promising in cosmetics industry is the camel milk. Currently, there is limited information in literature regarding use of camel milk in cosmetics and their benefits. Camel milk stands out from bovine milk following its unique therapeutic properties, chemical composition, making it a potential ingredient for the skincare and haircare products such as bath soaps and shampoos. The aim of this paper is to review available literature on camel milk composition and evaluate the contribution of camel milk constituents to the cosmetics.

2.1 Introduction

Globally, cosmetic usage has become a routine in human life due to their benefits to skincare, haircare, and makeup (Surya & Gunasekaran, 2021). For instance, COSMILE Europe report indicates that about 450 million European populations are utilizing personal grooming products such as shampoo, bath soap, shower gel, hair conditioner and skin care creams daily (Hall *et al*., 2007). Also, cosmetics industry has been growing yearly with an annual growth rate of 7% and cosmetics global market is projected to reach US$ 800 billion by 2024 (Liu, 2022).

According to several studies, cosmetics are vital in modifying human body outlook, enhancing body pleasant smell and to protect the body against bacterial attack (Kalasariya & Pereira, 2022). Antioxidants based cosmetics are found to have a range of benefits to human such as making skin to look younger and anti-inflammatory (Shivanand et al., 2010; Zehiroglu & Sarikaya, 2019), added that "natural cosmetics" such as herbal face cream, soaps, and shampoos contain essential nutrients, vitamins and minerals that protect human against some diseases like dandruff and acne.

Ghazali. (2017), reported that an increased demand for natural cosmetics is due to increased awareness on the effects of the chemicals present in the synthetic cosmetics. For instance, 1,4-dioxane a common ingredient in shampoos is reported to cause breast and skin cancer (Pereira & Pereira, 2018). Synthetic cosmetic formulations contain colorant which are aromatic ring and azo compound that consequently causes side effects such as allergies and asthma to consumers (Oymak *et al*., 2019). Additionally, in many countries, toxic cosmetic ingredients like hydroquinone, paraben and toluene are banned; clinical studies showed that paraben increases chances of skin cancer, toluene results to allergies while hydroquinone causes ochronosis (Hager et al., 2022; A. D. Khan & Alam, 2019). Moreover, synthetic cosmetics are made up of heavy metals such as lead and cadmium to enhance colour due to their ability of splitting of their d-orbitals that allows electrons to transit from low to high energy orbitals (Jin, 2023). However, these heavy metals expose consumers to disorders like cancer (Jaishankar *et al*., 2014). Following the above-mentioned side effects of synthetic cosmetics and increased awareness of pollution effects of petrochemicals, users have shifted to organic or herbal cosmetics due to their minimal side effects (Amberg & Fogarassy, 2019; Chanchal & Swarnlata, 2008). Avocado oil, neem, and aloe vera have been profoundly used in formulations of soaps and shampoos owing to their antifungal properties as well as their capability to battle oxidative stress (Chanchal & Swarnlata, 2008).

Recently, milk has become a good ingredient for skincare cosmetics made with natural products as it is loaded with casein and lactoferrin proteins which have anti-fungal and anti-cancer properties (Kazimierska & Kalinowska, 2021). In addition, dairy milk is a better component used in skincare cosmetics as it is reported to contain lactic acid for which *in vitro* experiments point out that it exfoliates dead cells from the skin and promotes growth of new cells (Bhardwaj *et al*., 2021; Ishikawa *et al*., 2021). Notably, in Indonesia, high quality cosmeceuticals for skin and haircare are crafted using goat's milk (Sumarmono, 2022). Lactic acid contained in goat milk moisturizes and soothes the skin in addition to shedding off the dead cells and promoting new cell growth (Molik *et al*., 2025).

Camel milk, the main source of livelihood for Arid and Semi-Arid Lands (ASALs) communities especially herders on long grazing periods (Faye et al., 2014), is reported as a rich source of α-hydroxyl acids (Mahmoud et al., 2021) ,which offer solution to skin diseases such as dermatitis and acne by promoting apoptosis in skin cells and enhancing collagen and elastin synthesis (Almeman, 2024). This places camel milk as a promising ingredient for cosmetics made from natural products, offering potential benefits against the mentioned skin diseases.

Kenya is ranked globally as the leading producer of camel milk as it records approximately 1.165 MMT of camel milk by volume every year (Oselu *et al*., 2022). However, despite Kenya being on the global map as a leading producer of camel milk, it is unfortunate that camel milk is underutilized due to unawareness of its cosmetic use and the market value. Also, little is documented on application of camel milk in the development of cosmetic products.

The focus of this paper is therefore to review recent literature on potential application of camel milk in production of toiletries such as bath soap and shampoo.

2.2 Methodology

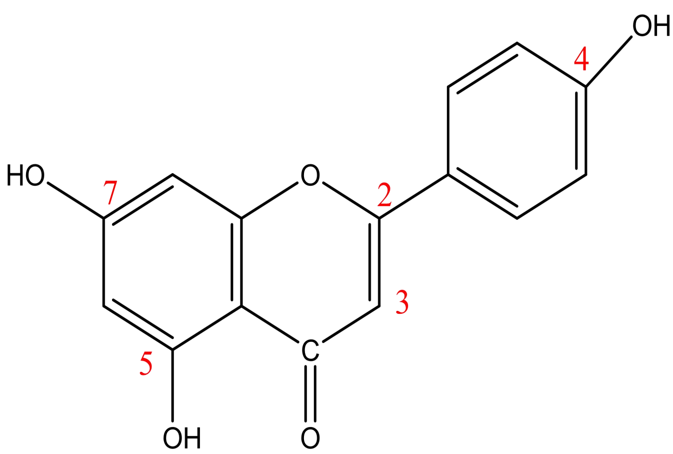
An electronic search was conducted across science direct, google scholar, and ResearchGate for articles published between 1997 and 2025 The keywords “camel milk,” “Goat milk,” “cow milk” “milk shampoo,” “therapeutic properties of camel milk,” and “natural products cosmetics” were used. This search generated 40 research articles and 15 duplicates. After screening, 13 studies on the bioactive compounds of camel milk, natural products in cosmetics and the use of cow and goat milk soap and shampoo formulation were included. Peer-reviewed articles published in English were considered, while incomplete texts, citations, and conference abstracts were excluded. Studies focusing primarily on the nutritional values of camel milk rather than its topical or therapeutic applications were also excluded.

2.3 Trends in Cosmetics from Natural Products

The use of natural products in developing cosmetics has attracted interest from consumers considering that natural products have minimal side effects (Liu, 2022). Yousif *et al*. (2008), reported that apigenin (4,5,7-trihydroxyflavone) a flavonoid synthesised from aromatic herbs and fruits showed protective effects in reducing skin tumour. In cancer cells, apigenin (4,5,7-trihydroxyflavone) causes apoptosis, or programmed cell death. In this process, the reactive oxygen species (ROS) pathway is activated, which lowers the generation of ROS and causes cell shrinkage, protein breakdown, and the inhibition of tumor growth by 2-deoxyribonucleic acid (DNA) (Liu, 2022). Natural antioxidants such as apigenin are used in cosmetics to protect skin from oxidative stress caused by UV radiation (Budzianowska *et al*., 2025). According to Chen *et al*. (2023), Apigenin contains 4,5,7-hydroxyl groups, which act as potent antioxidants by neutralizing free radicals through hydrogen atom transfer, single-electron transfer followed by proton transfer, and sequential proton loss electron transfer mechanisms. In these pathways, the hydroxyl groups are oxidized by free radicals to form unstable phenoxy radical intermediates, which subsequently produce stable radical adducts, thereby terminating the free-radical chain reaction.

Figure 2.1:

Chemical structure for 4,5,7-trihydroxyflavone



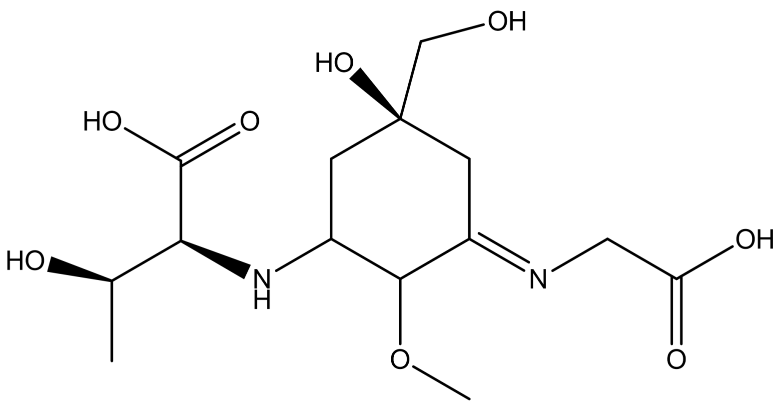
4,5,7-trihydroxyflavone

Source: Chen *et al*. (2023)

In addition, Porphyra-334, an alkaloid isolated from sea cucumbers and red algae is capable of softening skin by removing skin wrinkles (Chuang *et al*., 2014). Wrinkles and photoaging are associated with collagen degradation and UV irradiation, respectively (Wlaschek *et al*., 2001). Porphyra-334 inhibits the production of matrix metalloproteinase (MMP) enzymes that break down collagen and enhances the production of collagen and elastin in skin cells exposed to UV radiation (Ryu *et al*., 2014).

Figure 2.2:

Chemical structure for porphyra-334



Porphyra-334

Source: Nazifi *et al*. (2013)

According to Dini and Laneri (2021), the market demand for "green cosmetics" like skin care products has grown tremendously since besides enhancing beauty they also promote environment conservation. Today, the use of cosmeceuticals has emerged in the field of cosmetics in which cosmetics are formulated with bioactive ingredients that provide both therapeutic and cosmetics benefits to skin and hair.

Haryan *et al*.(2013), highlighted examples of natural products and their sources (Table 2.3.1) that have made their utilisation in cosmeceutical formulations. In addition, the researchers also noted rapid growth in personal care products as compared to other sector of natural products.

Table 2.1:

Natural products made from naturally synthesized compounds

Ingredient	**Action**	**Source**	**Product in market**
Beta hydroxyl acid	Antibacterial	*Salix matsudana*	Oxy med shampoo, skin medica face cream
Centella	Skin conditioning agent, improve skin texture reduces stretchmark	*Contella asciantica*	Himalaya nee face wash
Aloe-vera	Softens skin	Aloe-vera plant	Aloe-vera gel, naturesgel
Rosemary extract	Antioxidant, Antimicrobial	*Rosemarinus officinalis*	Loreal body cream
Boswelia	Anti-inflammatory and Anti-aging	*Boswellia serrata*	Aromaboswelia and Antiwrinkle cream
Neem oil	Antimicrobial	*Azadiracta indica*	Himalaya neem face wash

Source: Haryana & Sangeeta, (2013)

Animal products especially milk have recently found a wide application in cosmeceutical formulations (Kazimierska & Kalinowska, 2021). Milk possesses proteins which are antifungal, antioxidant, anticancer and antibacterial (Abdel & Alhaider, 2016). Research carried out by There *et al*.(2022), reported that soap formulated using goat milk has potent antimicrobial activity against microorganisms such as *Staphylococcus aureus* and *Escherichia coli*. Similarly, another study carried out by Sanchez *et al*. (2022) reported that addition of goat milk to shampoo improves its physicochemical properties such as conditioning performance, cleaning capacity and foaming ability. Table 2.2 presents a summary of dairy based cosmetic products.

Table 2.2:

Summary of cosmetic products using dairy ingredients

Product type	**Dairy ingredient**	**Bioactive components**	**Benefits**	**Source**
Soaps	Goat milk and goat milk cream and cow milk	Fatty acids and proteins, lactic acid	Antibacterial, exfoliation of dead cells and moisturizing	(Murti *et al.*, 2024; Susanti *et al.*, 2018)
Shampoos	Goat milk	Vitamin C and protein	Conditioning and hair growth	(Sánchez-Macías *et al.*, 2022)
Body lotions	Goat milk	Lactic acid, vitamin C and protein	Moisturizing, anti-aging and exfoliation	(Suciyanti *et al.*, 2015)

Source: Nasralla *et al.* (2022)

Camel milk's health and therapeutic properties, as well as its higher concentration of bioactive components than ruminant (goat and cow) milk, make it a promising ingredient for natural cosmetics, shown in table 2.2 (Yaseen & Hanee, 2019).

2.4 Chemical Composition of Camel Milk and their Cosmetic Potential

Numerous studies have indicated that chemical composition of camel milk rely on variables like seasonal variations, camels' health conditions, nutrition, management, geographical location and feeding regime (Khalesi *et al.*, 2017; Konuspayeva *et al.*, 2009; Muthukumaran *et al.*, 2022). For example, Al Haj *et al.* (2010) reported that between the year 1989 - 2009, C*amelus dromedarius* milk was found to contain on average 3.5% fat, 3.1% protein and 4.4% lactose. A decade later (2019) in Uzbekistan, Pak *et al.* (2019) on their comparative analysis of camel composition over winter and summer seasons, found that camel milk fat ,protein and lactose content are relatively lower in the summer period, and it was suggested to be attributed to changes in food supply. It is reported that unlike bovine milk, *Camelus dromedarius* milk fat has little content of carotene and minimal concentration of short chain fatty acids (Mohamed & Ayman, 2016). Also, Mohammadabadi. (2020), reported that camel milk contains essential proteins like lactoferrin and immunoglobulins which have anti-bacterial, anti-viral, anti-fungal and anti-microbial properties hence camel milk protect skin against infection. A study carried out by Jilo and Dechesa.(2016), reported that camel milk is rich in α-hydroxyl acids compared to bovine and goat milk. Also, the researchers established that camel milk has high content of magnesium and zinc minerals compared to bovine milk.

Camel milk is rich in liposome which is a potential ingredient of antiaging cosmetic products (Jilo & Tegegne, 2016). For instance, in Korea, a study explored the use of camel milk in cosmetics by preparing liposomes containing camel milk and testing them on human skin fibroblasts. The results showed that the camel milk liposomes increased collagen and hyaluronan synthase-3 (HAS-3) gene expression in a concentration-dependent manner while inhibiting elastase activity and matrix metalloproteinase (MMP)-1 gene expression. Additionally, the liposomes were found to regenerate ultraviolet B (UVB) damaged fibroblasts. These findings suggest that camel milk liposomes have potential as an anti-aging cosmetic ingredient (Choi *et al*., 2014).

Likewise, camel milk is an affordable cosmeceutical that doesn't cause any negative systemic or cutaneous reactions because of its constituents, which include water, peptides, alpha hydroxy acid, ascorbic acid, polyunsaturated fatty acid, and micronutrients (Mehta & Agrawal, 2020). The study also concluded that camel milk is a potential ingredient of a skin softener, anti-aging, anti-wrinkle, and photoprotective products.

2.4.1 Alpha-hydroxyl acids in milk

The alpha hydroxyl acids (AHAs) are weak organic acids in which the first carbon atom (α-carbon) from the carbonyl carbon is attached to hydroxyl group (Tang & Yang, 2018). Alpha-hydroxyl acid is naturally obtained from foods and milk and they constitute glycolic acid from sugarcane, citric acid from fruits and lactic acid from milk (Lewis & Suozzi, 2021).

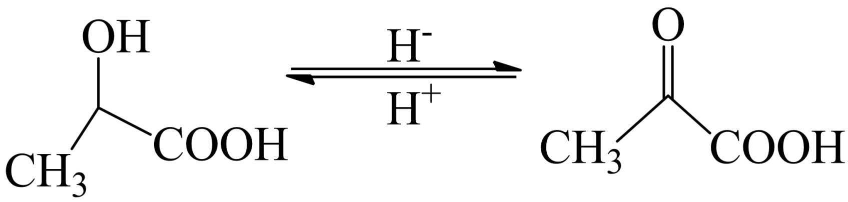
According to Algiert *et al*. (2019), lactic acid (2-hydroxypropanoic acid) is widely used in cosmetic formulations for its anti-aging, lightening, and moisturizing properties. For instance, anti-aging creams, age-spot removers, toners, and lactic acid powders are some of the commercial products that utilize lactic acid to enhance skincare (Bibilas et al., 2012). Similarly, (Baldo *et al*., 2010) investigated the clinical efficacy of a lactic acid-containing cream on patients with mild to moderate acne. The study involved 248 patients who applied the cream twice daily for 60 days. The results showed a high efficacy rate of 92.3% in acne treatment.

The researchers further reported that lactic acid molecule exists in two racemic mixture of D (-) and L (+) and that, out of the racemic mixture, L (+) enantiomer is more active biologically (Angermayr *et al*., 2016). In addition, L (+) lactic acid (S)-hydroxy propanoic acid) is a collagen stimulator (Christen, 2022).

Singh *et al*. (2014), observed that lactic acid acts as a suppressant of enzyme tyrosinase activities, an enzyme that regulates skin coloration (Zolghadri *et al*., 2019) hence lactic acid plays a role in brightening of the skin. In the aqueous medium of epidermis, hydroxyl group of the lactic acid undergoes deprotonation reaction forming pyruvic acid (Figure 2.3.1) (Algiert et al., 2019). Pyruvic acid formed stimulates fibroblast to produce collagen and elastin which give skin youthful outlook and repair of skin (Zhang et al., 2020).

Figure 2.3:

Deprotonation of lactic acid in aqueous medium



Source: Algiert *et al.*(2019)

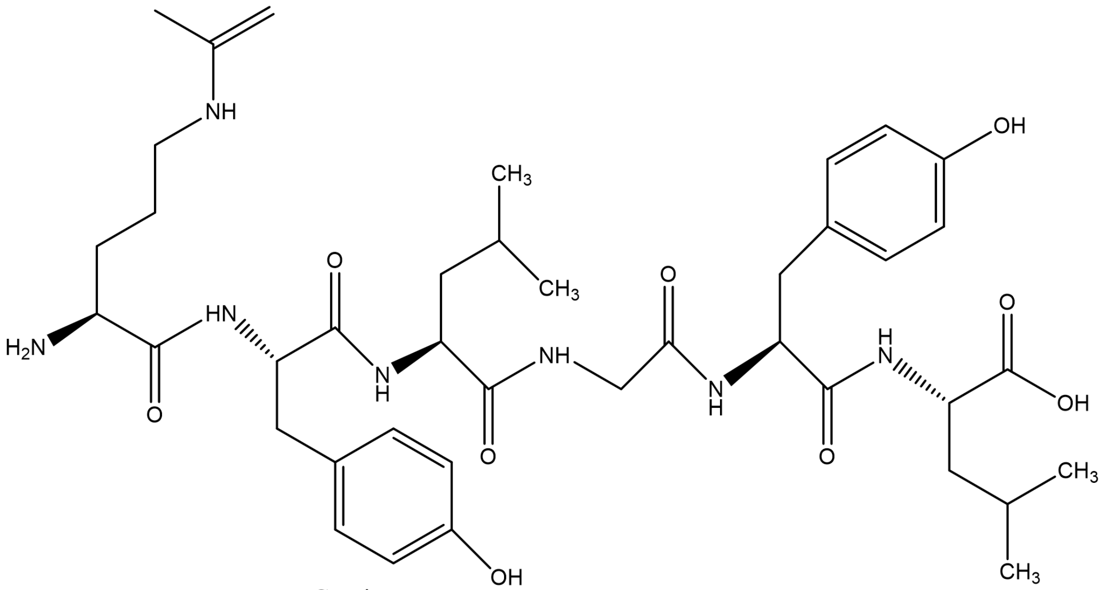
A study carried out by Scherdin *et al.* (2004), to compare the therapeutic activities of 2% concentration of both salicylic and lactic acids in treatment of 46 people having *Acne vulgaris* found that, lactic acid is more effective than salicylic acid. Similarly, another clinical study done by Sharquie *et al.*(2014), confirmed that 88% lactic acid gel/face wash is particularly good in treatment of acne scars. According to Jilo and Dechesa (2016), the lactic acid present in camel milk enhances the exfoliation of dead skin cells through breakdown of sugars that hold skin cells together, consequently, cell growth is facilitated.

2.4.2 Casein protein in milk

The casein is a milk protein responsible for white colour and is the main protein present in camel milk and makes about 87% protein (Khaskheli *et al.*, 2004). Casein is made up of four protein fractions: αs1-casein, αs2-casein, β-casein, and κ-casein and among the casein proteins, β-casein is more abundant in camel milk as compared to cow's milk (El-Agamy *et al.*, 2009). Also, hydrolysis of β-casein is easier compared to αs-casein. Casein reacts with sodium ions to form sodium caseinate which is used up to 96.9% in bath oils (Burnett *et al.*, 2022). Commercial casein skincare products for antimicrobial infections include bath oils and goat milk soap (Jilo & Tegegne, 2016). Also, casein nanofibers containing silver nanoparticles have antibacterial and biocompatible properties, which suggests they could be used in skin care products (Selvaraj *et al.*, 2018).

Figure 2.4:

Chemical structure for casein protein



Casein

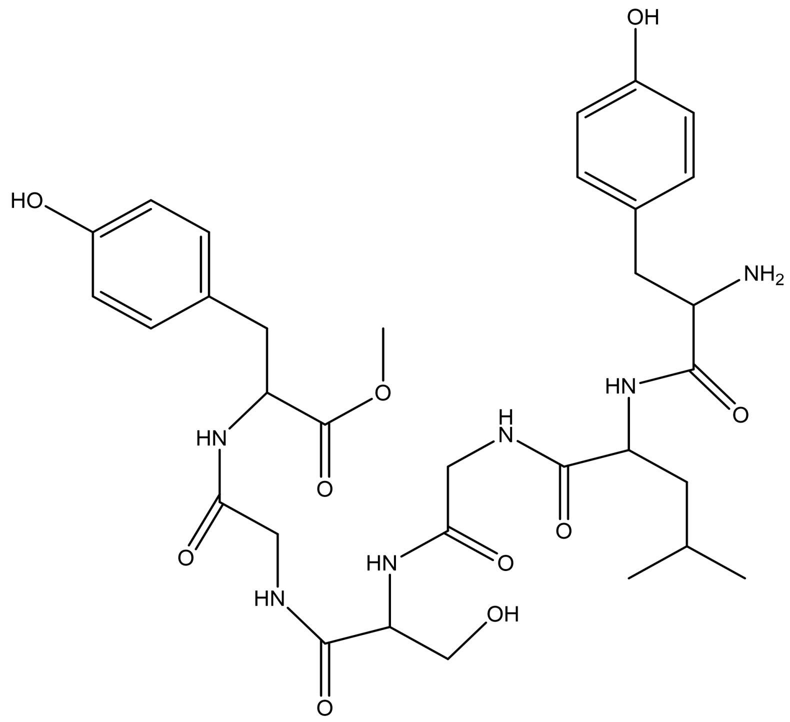
Source: Dhasmana *et al.*(2021)

2.4.3 Lactoferrin in milk

Lactoferrin as an iron binding glycoprotein, protects the human body against microbialand inflammatory infections (Hassoun & Sivamani, 2017). Bovine lactoferrin structure contained about 696 amino acids (Moore *et al.*, 1997). Upon completion of 8 weeks of clinical trials for acne treatment using bovine lactoferrin, Mueller *et al.* (2011), noticed a significant improvement among patients as 30 out of 39 patients involved in the clinical study showed decrease in acne papules and pustules. Also, a comparative study of antimicrobial spectrum of both bovine and human lactoferrin revealed strong microbial inhibitory effects of bovine lactoferrin (Biernbaum *et al.*, 2021). A range of scientific inquiries have consistently shown that bovine lactoferrin being anticarcinogenic stimulates immune system cells to release cytotoxic agents to hinder tumour cell growth (Cutone *et al.*, 2020). Likewise, *in vitro* study carried by Hosam *et* *al*.(2013), revealed that camel milk lactoferrin has a significant ability to reduce growth of cancer cells. Camel milk lactoferrin reduces cancer growth by 56% as reported by Habib *et al*.(2013), Researchers also added that anti-cancer property of camel milk lactoferrin could be because of its direct cell cytotoxicity and anti-angiogenic action which involves cutting off the blood supply to tumor cells (Ibrahim *et al*., 2022).

Figure 2.5:

Chemical structure for lactoferrin



Lactoferrin

Source: Mofidian *et al*. (2019)

2.5 Camel Milk as Cosmeceuticals Ingredient

2.5.1 Skin cancer

According to World Health Organization report (WHO, 2020) cancer prevalence is approximately 18.1 million, with melanoma the skin cancer ranked number 17 out of 33 cancers. Further, based on the increased cancer cases yearly, the report projected that the global cancer cases could double to 27-37 million cancer cases by 2040. Exposure to chemical ingredients in synthetic cosmetics is found to be one of the way that causes skin cancer since skin absorbs about 60% of the chemical ingredients (A. Alnuqaydan & Sanderson, 2016). For instance, King. (2011), reported that most of the shampoos are formulated using nitrosamines which are carcinogenic. Following the escalating global cancer prevalence and the anticipated increase in cancer cases, there is a growing need for ground-breaking approaches in cancer treatment and prevention, including in the field of cosmetics.

Camel milk is promising in the treatment of tumor and skin cancer therapy as it is packed with lactoferrin that *in vivo* and *in vitro* experiments have demonstrated that is anti-cancerous (Muthukumaran *et al*., 2022). In addition, Hasson *et al*.(2015), also claims that camel milk provides an avenue for inhibition of growth of breast cancer cells BT-474 cells. Similarly, a study on anticancer effects of ruminant milk carried by Shariatikia *et al*. (2017), found that camel milk has greatest cytotoxic activities to counter MCF7 breast cancer causing cells compared to other ruminants' milk. Furthermore, milk fat globule membrane of the dromedarius camel milk has the ability of elimination of cancer cells (Boukria *et al*., 2020). However, it is worth noting that camel milk's potential anti-cancer benefits are still in the early stages of research. There are few large-scale clinical trials in humans to confirm these effects (Miniawy *et al*., 2017). Additionally, more research is needed to determine the specific mechanisms by which camel milk components interact with cancer cells.

2.5.2 Dandruff and Seborrheic dermatitis

The global prevalence of *Seborrheic dermatitis* stands at 5% while that of Dandruff is about 50% (Elewski, 2005) Dandruff and *Seborrheic dermatitis* are allied to itchy and peeling of skin. Both dandruff and *S. dermatitis* are fungal skin diseases that affect sculp (Borda & Wikramanayake, 2015). Additionally, skin regions with thick sebaceous glands such as scalp and face are susceptible to *Seborrheic dermatitis* infection(Borda & Wikramanayake, 2015). In Elewski and Ravikumar reports (Elewski, 2005; Ravikumar, 2018), dandruff is caused by gathering of corneocytes in the scalp and people aged within the range of 15-50 years are more susceptible to dandruff, as this is the period during which the sebaceous glands are most active.

S. dermatitis is currently cured using anti-inflammatory steroids, however, the prolonged exposure of skin to steroids is reported to be associated with adverse effects like peeling of skin and acne (Kastarinen *et al*., 2015). Also, the frequent use of shampoo containing antifungal agents like salicyclic acid is remarkably effective in controlling *S. dermatitis* (Reuger, 2019).

Camel milk can be a promising remedy for both dandruff and *S. dermatitis* as it is reported to contain casein peptides (Rafiq *et al*., 2016), that are made up of αs1, αs2, β and κ casein which are reported to have antibacterial, antiviral, antifungal and antioxidant activities (López-Expósito *et al.*, 2007). Moreover, Rasheed. (2017), reported that N-acetyl-β-d-glycosaminidase present in camel milk has shown antimicrobial activity. Dromedary camel milk is loaded with natural phospholipids that initiate healing of skin through production of collagen (Alkoofee & Aljaber, 2018).

2.5.3 Acne scars

According to Fabborocini *et al*. (2010), more than 90% of teenage population are susceptible to acne infection and about 13% of the cases persists up to adulthood. The study added that the two types of the scars; hypertrophic and keloidal scars are caused by the accumulation of collagen. Kontochristopoulos *et al*. (2017), reported that alpha-hydroxy acids such as glycolic acid, pyruvic acid and lactic acid are one of the biochemical peeling agents used in the control and management of the acne scars as they aid in elimination of dead skin. In India, the pilot study on peeling effects of lactic acid on acne scars done by Sachdeva (2010), found that 92 % pure 2-hydroxypropanoic acid (lactic acid) showed an excellent improvement in peeling of superficial and lightening of acne scars among patients with dark skin. In addition, Sharquie *et al.* (2014), found 88% pure lactic acid to have greater efficacy in treatment of *A. vulgaris* and acne scar in patients with dark skin. *Camelus dromedarius* milk contains an α-hydroxyl acid that smoothens skin through elimination of dead skin cells thus effective for acne treatment (Jilo & Tegegne, 2016). Also, a study carried out by (Luay *et al.*, 2019) on antimicrobial and anti-inflammatory activity of camel milk against *Propiobacterium acne* found that camel milk derived immune proteins and peptides have antimicrobial and anti-inflammatory activity against the bacteria. The study findings pave the way for potential use of camel milk in cosmetics to manage *A. vulgaris* and other skin infections such as *Serborrheic dermatitis* and dandruff.

2.5.4 *Tinea pedis* (fungal infection on the foot)

Tinea pedis is a contagious fungal infection of the feet that majorly occur between the toes and soles (Kumar *et al*., 2011). The *T. pedis* caused by too much accumulation of moisture between the toes and it is linked to itching and burning.

Globally, 15% of people have *T pedis* (Bell-Syer *et al*., 2012). Yamauchi *et al*.(2006), carried out a clinical study on patients with *T. pedis* and reported that bovine milk lactoferrin has a healing effect. Also, in another clinical trials where 37 selected adults with *T. pedis* were given doses of bovine lactoferrin daily for 56 days, Yamauchi *et al*. (2000), noticed a decreased symptoms among the patients. One millilitre of camel milk contains about 0.22 mg of lactoferrin which is much higher compared to cow milk (Jilo & Tegegne, 2016). Therefore, camel milk can be a good replacer of bovine milk in treatment of *T. pedis*.

2.6 Use of Camel Milk in Cosmetics

2.6.1 Camel milk in body wash (bath soaps)

Camel milk besides being a source of food, is replacing other milks in cosmetics due to its therapeutic properties (Izadi *et al*., 2019). Camel milk is rich in alpha hydroxy acids such as lactic acid that help in elimination of dead cells and spots on the skin (Jilo & Tegegne, 2016). The alpha hydroxyl acids are often used in production of skincare cosmetics products like bath soap (Bibilas et al., 2012).

Mohammadabadi. (2020), reported that camel milk is rich in essential proteins like lactoferrin and immunoglobulins which have anti-bacterial, anti-viral and anti-fungal hence camel milk protect skin against infection. It is reported that vitamin C, zinc, and magnesium minerals present in camel milk are good antioxidants hence aids skin to relieve oxidative stress (Izadi *et al*., 2019). Furthermore, camel milk contains lanolin which is a moisturizer that ensures that the skin is hydrated (Mahmoud et al., 2021). The therapeutic nature of camel milk on skin health makes it a better ingredient for natural body wash. Consumers believe that camel milk has more therapeutic and medical characteristics than cow milk, which drives demand (Hassani *et al*., 2022). Similarly, the health benefits of camel milk products have been found to enhance the willingness to purchase the products, particularly among people who suffer from lifestyle disorders (Mohan *et al*., 2020).

2.6.2 Milk in hair products

Shampoo as a hair care product serves a dual cosmetic function of cleansing and enhancing hair beauty (Draelos, 2010). Its primary role relies in maintaining scalp and hair hygiene, a function heavily influenced by its formulation (Milanović *et al*., 2020). According to Mainkar *et al*. (2001), naturally formulated shampoos are on demand as they contain ingredients which are chemically inert and biocompatible to the users.

Research has demonstrated that goat milk has been successfully included into shampoos due to its health and therapeutic benefits (Sánchez-Macías *et al.,* 2022). According to the study, goat-milk shampoo provided good conditioning performance and had a 30-day shelf-life period. A study done by Susanti *et al*.(2018), found that liquid soap formulas with 15% cow's milk were stable for 28 days due to well-balanced ingredients and compatibility within the formula preventing degradation over the period.

2.7 Conclusion

The shift towards cosmetics made from natural products is caused by the fact that natural cosmetics are biodegradable and have mild reactions to use skin compared to synthetic cosmetics. Milk, whether from cows, goats, or camels, has emerged as a valuable ingredient in cosmetics, offering numerous advantages. Camel milk stands out due to its unique chemical composition such as essential proteins like lactoferrin and immunoglobulins, which possess antibacterial, antiviral, and antifungal properties. Camel milk also boasts an abundance of alpha-hydroxy acids (AHAs), such as lactic acid that are involved in exfoliating dead skin cells, stimulating collagen production, and brightening the skin. Moreover, casein, a predominant protein in camel milk, has demonstrated potential in cancer treatment, and lactoferrin exhibits a carcinogenic property, making camel milk a promising candidate for cosmeceuticals. Camel milk's potential role in preventing skin cancer, treating dandruff and *Seborrheic dermatitis*, and addressing acne scars makes it an attractive choice for skincare products.

The benefits of camel milk in cosmetics are compelling, but further research is required to fully exploit its potential. Continued scientific research will assist to validate these preliminary findings and optimize the usage of camel milk in cosmetic compositions. Furthermore, studying the market impact of camel milk-based cosmetic products will provide credible data on customer acceptance and profitability. Camel milk may play an important role in the future of cosmeceuticals if its therapeutic benefits are supported by scientific evidence.

CHAPTER THREE

Comparative Review of Milk-Enriched and Plant-Based Soaps: Formulation, Composition and Skin Benefits

Abstract

Soap remains a widely used skincare product valued for both cleansing and skin-enhancing benefits. Traditional formulations have evolved to include milk-enriched and plant-based variants, increasingly popular in both artisanal and commercial markets. Milk-based soaps, particularly those formulated with goat, cow, or sheep milk, are rich with proteins, vitamins, and fatty acids that nourish skin, hydrate, exfoliate, and repair skin barriers. Goat milk soaps are especially great for sensitive and inflammatory conditions as they balance the pH and nourish the skin. In contrast, plant-based soaps employ oils such as olive, coconut, and shea, often mixed with herbal extracts that impart antioxidant and antimicrobial effects. The differences in ingredients between milk-based and plant-based soaps directly affect how the soaps perform. Milk-based soaps tend to have more saturated fats and mineral compounds, which enhance creaminess and skin nourishment. On the other hand, plant-based soaps are richer in unsaturated oils, giving them better stability and a longer shelf life. Recent innovations in milk-based soaps include adding probiotics to help balance the skin's natural bacteria, encapsulating milk proteins to improve their stability and effectiveness, and using eco-friendly extraction methods to preserve the nutrients and benefits found in milk. Analytical techniques like FTIR helps in characterisation of the functional groups provides insight on complete saponification and presence of milk proteins. Despite growing consumer interest, comparative studies remain limited. This review highlights current developments in formulation, composition, technology, and functionality of milk-enriched and plant-based soaps, offering insights for researchers and informed consumers.

3.0 Introduction

Soap remains one of the most widely used skincare products globally, valued not only for its cleansing function but also for its ability to improve skin health and sensory properties (Vidal *et al*., 2018). Traditionally produced through saponification, a reaction between fats or oils and an alkali, soap formulations have undergone significant diversification in recent decades, incorporating various functional additives to meet the evolving needs of consumers. Notable developments include milk-enriched and plant-based soaps, which are two growing niches in both artisanal and commercial skincare markets (Paul *et al*., 2019).

Milk-enriched soaps often include animal milks such as goat, cow, and increasingly plant-based milks like almond and coconut. These milks are rich in bioactive compounds, including proteins, lipids, vitamins (especially A, D, and E) and lactic acid, which work together to improve skin hydration, promote gentle exfoliation and support barrier repair (Walther *et al*., 2022). Goat milk, in particular, contains capric and caprylic acids, which are known to support the skin microbiota and restore pH, making such formulations beneficial for dry, sensitive, or inflammatory skin conditions, such as eczema.

Conversely, plant-based soaps are made with vegetable oils such as olive, shea, or sunflower, often enriched with herbal extracts like neem, *A. vera*, turmeric, or tea tree oil. These ingredients are widely reported to provide antioxidant, antimicrobial, and anti-inflammatory benefits. Coconut oil is known to exhibit both moisturizing and antibacterial effects, while olive oil helps maintain soft and elastic skin due to its high oleic acid and polyphenol content (Banik *et al*., 2025). From a formulation science perspective, the inclusion of milk or plant extracts significantly alters soap's emulsion stability, pH, fatty acid profile and shelf life. Milk-derived proteins can enhance emulsification but may also introduce microbiological stability concerns, whereas certain plant oils improve hardness and lathering properties (Vidal *et al*., 2018). These differences extend to the chemical composition: milk-based soaps tend to contain more saturated fats and calcium-bound structures, while plant-based variants often feature unsaturated fatty acids with higher oxidative stability and bioactivity (Reyes-Jurado *et al*., 2023).

Recent innovations in milk-based soap production include the use of microencapsulation techniques to stabilize milk proteins, the substitution of animal milks with fortified plant milks and the development of probiotic-enhanced or dermatologically targeted formulations. Meanwhile, plant-based soaps have seen advancements in green extraction technologies, biodegradable packaging and multi-functional botanical blends to deliver combined therapeutic and cosmetic benefits (Banik *et al*., 2025). Despite the popularity of both milk-enriched and plant-based soaps, comprehensive comparisons remain limited. Most studies tend to focus on one formulation type or specific ingredients rather than providing a broader, comparative analysis. This review examines the formulation, composition, innovations, and functional properties of both milk and plant-based soaps, aiming to inform research, guide formulation, and support consumer and dermatological choices.

3.1 Methodology

A comprehensive literature search was performed using science direct, google scholar, and ResearchGate to identify studies published between 2014 and 2025. Search terms included "milk soap," "physicochemical parameter of soap," "analytical techniques in soap analysis," "chemistry of saponification," "antibacterial properties of soap," and "natural formulation chemistry of soap." This search yielded 64 research papers, with 27 identified as duplicates. Following screening, 19 publications focusing on the soap formulation, physicochemical evaluation of soap, antibacterial efficacy and dermatological benefits of soap were selected for inclusion.

Only peer-reviewed articles published in English were considered, while incomplete texts, citations and conference abstracts were excluded. Also, studies on physicochemical evaluation, antibacterial and sensory evaluation of commercial soaps were omitted.

3.2 Formulation Science in Soaps

The formulation of soap involves careful selection and proportioning of oils, additives and processing methods to achieve desired properties such as lather, hardness, skin compatibility and shelf stability (Borhan *et al*., 2014). In both milk-enriched and plant-based soaps, formulation science dictates how functional ingredients interact with the soap matrix and influence performance. In milk-based soaps, formulation challenges include managing microbial stability and avoiding browning due to Maillard reactions between milk proteins and residual alkali (Pawar et al., 2024). To mitigate this, milk is often added post-saponification or as a powdered form during the emulsification stage. Additionally, preservatives or antioxidants may be used to extend shelf life and prevent rancidity (Chatterjee & Mishra, 2020). Plant-based soaps require a balanced fatty acid profile from oils to optimize lather and conditioning. For example, coconut oil provides cleansing power and foaming, whereas castor and olive oils improve solubility and skin feel (Vidal *et al*., 2018). Additives such as herbal extracts or essential oils are typically introduced during the cooling phase to preserve their bioactivity (Paul *et al.*, 2019). Soap making methods such as the cold process, hot process, and melt and pour techniques are chosen based on ingredient sensitivity and the intended scale of production (Nayak et al., 2024).

3.2.1 Chemistry of saponification

Saponification involves the alkaline hydrolysis of triglycerides into fatty acid salts and glycerol (Alum and Nnchi, 2024). The process has been known since ancient times but remains highly relevant due to ongoing innovations in cosmetic formulation and the resurgence of interest in natural and functional skincare products.

The versatility of saponification allows for the incorporation of diverse ingredients, including animal-derived milks and plant-based oils, but also introduces formulation challenges that depend on the precise chemical reactions involved. Saponification is a nucleophilic acyl substitution reaction in which hydroxide ions (OH^-) attack the carbonyl carbon of ester bonds in triglycerides. A triglyceride molecule consists of a glycerol backbone esterified with three fatty acids (Ivanova et al., 2022). When treated with a strong base such as sodium hydroxide (NaOH) or potassium hydroxide (KOH), these ester linkages are cleaved, yielding glycerol and the sodium or potassium salts of the respective fatty acids (Banik *et al*., 2025).

3.2.2 Chemical composition of milk and plant-based soaps

The chemical composition of both milk-based and plant-based soaps is determined by the ingredients like oils and additives used in the formulation. Milk contain fatty acids such palmitic, stearic and oleic alongside other constituents such as lactic acid, casein, vitamins (Foroutan *et al*., 2019). When milk is incorporated in soap formulations, these components contribute to enhanced moisturization, skin nourishment, and mild (Gandhi et al., 2025). Typically, oils from botanical sources like coconut, olive, palm, or neem are used to formulate plant-based soaps. These oils are abundant in naturally occurring bioactive substances, such as polyphenols, flavonoids, terpenes, and antioxidants, as well as essential fatty acids, which support the soap's moisturising, cleansing, and antibacterial qualities (Cermeño *et al*., 2024). Plant extracts containing secondary metabolites such as saponins, alkaloids, tannins, flavonoids, and steroids significantly influence key soaps physicochemical properties including pH, foam formation, hardness, and moisture content (Ashraf & Rafiq, 2025). These phytochemicals exhibit antibacterial activity through various mechanisms including bacterial membrane damage and virulence factor suppression (Wagh, 2025). Herbal soaps formulated with extracts from plants like *Curcuma longa*, *Azadirachta indica*, *Aloe barbadensis* demonstrate effective antimicrobial properties against pathogens such as *E. coli* while maintaining skin-friendly pH levels (H. Khan et al., 2025).

3.2.3 Dermatological and functional benefits

Apart from cleansing, milk-based and plant-based soaps impart dermatologic and functional benefits when the bioactive compounds are used in the formulation (Ashraf et al., 2016; Seetha et al., 2021). Both milk-enriched and plant-based soaps are formulated to meet consumer demand for mild, skin-compatible products that also provide additional therapeutic benefits (Pardhi et al., 2025; Waghmare et al., 2025). The skin benefits of milk-based soaps, especially those formulated with goat, cow, or camel milk, are due to the composition of vitamins, liposomes, immunoglobulins and alpha-hydroxyl acids (Jilo & Tegegne, 2016). These milk chemical substances are associated to the moisturizing, exfoliating, and pH-balancing properties of the soaps, making them ideal for individuals with skin infections, dry, or inflamed skin (Gandhi et al., 2025). Singh *et al* (2014), reported that alpha-hydroxyl acids act as a suppressant of enzyme tyrosinase activities, an enzyme that regulates skin coloration. Alpha hydroxyl acids are deprotonated to pyruvic acid which stimulates fibroblast to produce collagen and elastin and then give skin youthful outlook and repair of skin (Algiert et al., 2019). Several studies have shown that goat milk soaps can benefit individuals with eczema and acne-prone skin.

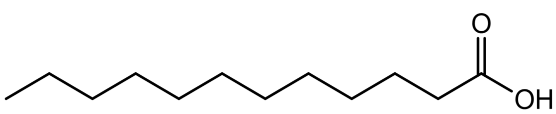
Conversely, plant-based soaps derive their dermatological benefits from essential vegetable oils and phytochemicals. Soaps formulated with plant extracts rich in phytochemicals such as flavonoids and phenolics are reported to reduce acne infections (Ogunbiyi & Enechukwu, 2021). Herbal soap containing flavonoids was found to reduce skin inflammation and irritation. Plant-based soaps can exhibit antibacterial activity due to the presence of natural compounds like saponins, tannins, and essential oils found in various plants. These compounds can disrupt bacterial cell walls, inhibit bacterial growth, and have demonstrated effectiveness against both Gram-positive and Gram-negative bacteria (Priyanka et al., 2025).

3.3 Recent Innovations and Trends in Milk-Based Soaps

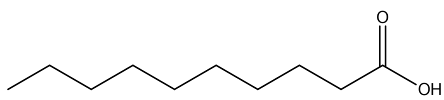
Milk soaps have emerged as a natural skincare product due to their skin benefits. These soaps are loaded with bioactive compounds and fatty acids naturally present in milk which contribute to skin smoothening and nourishment (Sutarna *et al*., 2022). In soap formulation, beneficial fatty acids are selectively utilised for their functional properties: lauric (C12:0), myristic (C14:0), palmitic (C16:0), and stearic (C18:0) acids enhance hardness and foamability, while capric (C10:0) and oleic (C18:1) acids are associated to soaps smoothening and moisturizing effects (Putri, 2023; Sutarna *et al*., 2022). These milk benefits have led to formulations of various milk soaps. Murti *et al*. (2024), formulated goat milk bar soap that had antibacterial and rehydration effects.

Figure 3.1:

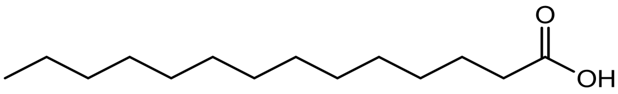
Chemical structure for fatty acids in camel milk cream



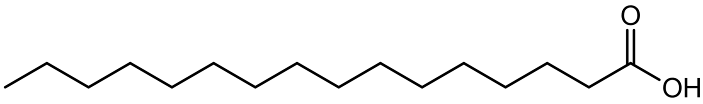
Lauric acid



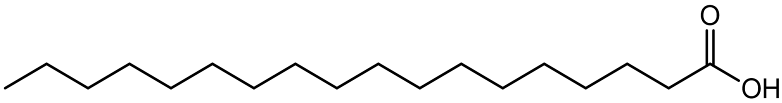
Capric acid



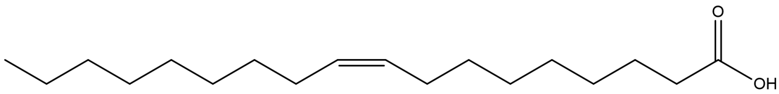
Myristic acid



Palmitic acid



Stearic acid



Oleic acid

Source: Harwood & Scrimgeour (2007)

Also, Fatchiyan *et al*. (2023), reported that sheep milk soap has antimicrobial activity and stable shelf-life. Among the trends, the use of camel milk in cosmetic formulations soaps has emerged as recent innovation. Camel milk as a potential ingredient for bath soaps since it is loaded with liposomes and alpha-hydroxy acids, which are attributed to anti-aging and exfoliating properties (Yaseen & Hanee, 2019). These components not only enhance the soap's therapeutic value but also contribute to improved skin hydration and antibacterial protection, making camel milk a novel ingredient in soap formulations (Luay *et al*., 2019).

3.4 Characterization Techniques

3.4.1 Fourier transform infrared spectroscopy

The Fourier Transform Infrared Spectroscopy (FTIR) is one of the powerful and widely used analytical techniques in characterization of the functional groups in various materials, including cosmetic products like soap (Siddique, 2024). The infrared part of electromagnetic spectrum is divided into three regions namely; far infrared region which lies between (100-400 cm^{-1}), mid-infrared region (400-4000 cm^{-1}) and near infrared region (13000-4000 cm^{-1}) (Stuart, 2004). Additionally, the FTIR spectroscopy operates on the fundamental principle that molecules absorb infrared radiation, causing vibrational modes including stretching and bending of electric dipoles, which transition to excited states (Guerrero & Patience, 2020).

In soap analysis, the characterisation of the functional groups provides insight on complete saponification reaction by observing C-O-Na peak as well as the identification of the absorption bands corresponding to un-saponified fatty acids (Mirghani *et al.*, 2002). FTIR is useful in comparing the fatty acid composition of plant-based and milk-enriched soaps. In milk-enriched soaps, the infrared technique is used to characterize the protein-related functional groups such as amide I and amide II which are associated to absorption bands near 1654 and 1544 cm^{-1}, respectively (Eid et al., 2022; Nicolaou et al., 2010). In the characterization of milk cream soaps, milk cream is first characterized to detect the absorption bands that correspond to R-COOH bonds of the triglyceride esters of the fatty acids (Rohman & Yaakob, 2011). Notably, after the saponification reaction of fatty acids present in cream with the sodium hydroxide, disappearance of peak for R-COOH and emergence of R-COONa are expected. Muijlwijk *et al.* (2024), used this techniques to study the fatty acid soaps.

3.5 Analytical Methods for Determination of Physicochemical Properties of Soaps

The use of analytical methods is essential for determining the physicochemical properties of soap. These methods provide both quantitative and qualitative data on key parameters such as total fatty matter, saponification value, alkali content, pH, moisture content, hardness, fatty-acid composition and peroxide value (Endo, 2018). Classical gravimetric and titrimetric procedures remain the primary approaches for assessing total fatty matter, free alkali and saponification values (Betsy *et al.*, 2021), whereas potentiometric techniques are commonly employed to measure pH, a critical parameter for evaluating product safety and skin compatibility (Abdul *et al*., 2024).

Moisture content is typically determined by oven drying but can be measured more accurately using sensitive techniques such as Karl Fischer titration (Tavčar *et al*., 2012; Vivian *et al.,* 2014). Advanced chromatographic methods, including gas chromatography–mass spectrometry (GC-MS) and high-performance liquid chromatography (HPLC), are routinely used to profile the fatty-acid composition of soaps (Jacob *et al*., 2024). Rohman and Yaakob (2011) reported the application of Fourier-transform infrared spectroscopy with attenuated total reflectance (FTIR-ATR) for confirming functional groups and monitoring the saponification process. Despite the wide application of these analytical techniques, their use in the physicochemical analysis of soaps remains insufficiently standardised, particularly for complex matrices such as milk-enriched formulations.

3.6 Physicochemical Properties of Importance in Soap

Soap is a surfactant formed primarily through the saponification reaction between triglycerides (fats or oils) and an alkali, such as sodium hydroxide (NaOH) (Alum and Nnchi, 2024). Soap quality is largely determined by its physicochemical properties such as pH, moisture content, total fatty matter, free alkali, foaming ability and hardness (Legesse & Mengisteab, 2024). Physicochemical properties of cosmetic formulations are fundamental to consumer acceptance and product performance (Montenegro *et al*., 2015).

3.6.1 Acidity/alkalinity of soap solution (pH)

The pH refers to a measure of the acidity or alkalinity of an aqueous solution (Tarun *et al*., 2014). The pH of a soap solution is an important parameter as it determines the soaps dehydrative effect and skin irritability (Hawkins *et al*., 2021). Vivian *et al*. (2014) reported that high pH values in soaps are attributed to presence of hydroxide ions (OH^-)

which is as a result of incomplete hydrolysis fatty acids during saponification reaction. Several researchers have reported that soaps have pH values ranging from 9 to 11 (Sukeksi *et al*., 2021; Vivian *et al*., 2014) Additionally, Habib *et al*. (2016), on the study of physicochemical properties of commercial soaps in Bangladesh market reported that bath soaps have a pH values that ranges between 9.69 to 7.79 while laundry soaps was observed between 9.92 to 10.13. High pH can neutralize the skin's natural acid layer, leading to dryness and irritation (Proksch, 2018).

3.6.2 Moisture content

The moisture content of soap is a key parameter in determining its shelf life. Excess moisture can react with any remaining un-saponified fats over time, leading to hydrolysis and the production of free fatty acids and glycerol during storage (Abdul *et al*., 2024). Moisture content of below 29.05 % is recommended for the bar soap to prevent microbial growth and premature deterioration (Ogunsuyi & Akinnawo, 2012). Milk-enriched soaps retain more moisture than plant-based soaps due to hydrophilic components like lactose and proteins, which enhance softness and moisturization but may increase susceptibility to microbial spoilage if not well preserved (Vidal *et al*., 2018). On the other hand, plant-based soaps especially those formulated with oils rich in saturated fatty acids like coconut or palm oil tend to have lower moisture content, which improves their stability but reduces their hydrating effect on the skin (Alum and Nnchi, 2024).

3.6.3 Total fatty matter

Total fatty matter (TFM) is the sum of fatty acids present in soap (Betsy *et al*., 2021). Total fatty matter rehydrates skin (Abba *et al*., 2021) In milk soaps, such as goat milk soap and cow milk soap, TFM is reported to be relatively high due to the fat content in milk. For instance, Gandhi *et al*. (2025), reported that goat milk soap is rich in super fat that soothes and hydrates skin. Also, on physicochemical study of goat milk formulated with expired powered milk found that milk fat contribute to smooth skin feel (Ali *et al.*, 2023). Conversely, botanical soaps tend to show variability in TFM, which largely depends on the type of oil used in the formulation. Soaps formulated with oils rich in saturated fatty acids have high percentage of total fatty matter (Betsy *et al*., 2021). Even though, both plant-based and milk-enriched soaps can achieve TFM values that meet the set standards, milk-enriched soaps are rich in milk lipids which attribute to rich foam and skin rehydration (Dastidar *et al*., 2023). Milk soaps offer skin emollient and rehydration whereas plant-based soaps have a desired texture and cleansing due fatty acid composition (Siti et al., 2024).

3.6.4 Alkali content

Soap abrasiveness is attributed to percentage level of alkali content. Alkali content refers to the residual amount of free alkali (NaOH or KOH) that remains unreacted during the saponification reaction (Vivian *et al.*, 2014). High alkali content in soap is caused by the high lye to fatty acids ratio in the formulation or percentage purity of the lye (Alum and Nnchi, 2024). In soap formulations, the amount of lye is determined by the saponification value of oils to be used (Hussaini *et al*., 2025).

Different oils such as coconut, palm, and olive oils have different saponification values. Coconut oil requires a higher amount of alkali and thereby producing soaps with strong cleansing power but also higher potential for skin dryness (Iriany et al., 2020). Alkali content can be reduced by addition of super fat or inclusion of unsaturated fatty acids (Abba *et al*., 2021). Habib *et al*.(2016), reported that the free caustic alkali content ranged from 0.00% to 0.62% in toilet soaps and from 0.14% to 0.99% in laundry soaps. There *et al*.(2022) , reported alkali content 0% in goat milk-based handmade soap which caused no skin irritation. From the literature, the alkali content of both plant-based and milk-enriched soaps rely on the free alkali content in the soap which is not bonded to fatty acids (Habib *et al*., 2016).

3.6.5 Foaming ability

Soap foaming ability is parameter which determined by the nature of fat or oil used in the formulation. Milk soaps are associated to a creamy and stable foam with a moderate volume due to proteins and lipids present in milk (Chasanah *et al*., 2022). Foamability of plant-based soaps vary with oil composition. Oils rich in saturated fatty acids produces soap with good foamability and cleansing power (Arias *et al*., 2023; Cermeño *et al.*, 2024). While milk-enriched soaps provide creamier, more stable foam with an improved moisturising feel, plant-based soaps typically have higher foaming ability in terms of volume and bubble quantity (Thao *et al*., 2022).

3.6.6 Hardness

Soap hardness is a physical parameter that influences durability and user experience. The percentage composition of saturated and unsaturated fatty acids significantly influences the hardness of soap as saturated fatty acids contribute to hardness while unsaturated fatty acids is associated to softness (Alum and Nnchi, 2024). Plant-based soaps formulated with oils rich in saturated fatty acids such as coconut oil and palm oil exhibit higher hardness since they are rich source of saturated fatty acids (Shoge, 2021). Harder soaps have lower moisture and dissolve more slowly, improving storage stability Harder soaps have lower moisture and dissolve more slowly, improving storage stability (Fatchiyah *et al*., 2023). In contrast, milk-enriched soaps often show reduced hardness owing to the incorporation of milk proteins, lactose, and other hydrophilic constituents. These ingredients, while enhancing moisturizing and conditioning effects on the skin, increase the soap's water retention capacity, resulting in a softer bar (Vidal *et al*., 2018). Additionally, milk such camel milk is rich in polyunsaturated fatty acids which contributed to softer soaps with high moisturizing effect (Mohamed & Ayman, 2016). Therefore, balancing hardness in soap formulations is essential not only for product stability and longevity but also for optimizing skin benefits and user satisfaction. The plant oils and milk blends of dual oil blends or hardening additives in milk-enriched soaps is often employed to compensate for the softness imparted by dairy components. To optimize the hardness, softness and skin moisturizing effects, formulators often blend plant oils and milk in soap formulations.

3.6.7 Shelf life

Shelf-life refers to the period a cosmetic product maintains its physical, chemical, microbial, and sensory stability from production to expiry (Guaratini *et al*., 2006). The formulation and storage conditions greatly impact the shelf-life of a soap. Stability of a milk-based soap depends on complete saponification and moisture content. Excess water in soap formulations has been reported to react with un-saponified fatty acids, resulting in the formation of glycerol and free fatty acids, which may compromise the product's stability (Abdul *et al*., 2024). Shelf life and antimicrobial activity evaluations showed that soaps formulated with milk retain physicochemical properties effectively over storage, for instance, Murti *et al*. (2024) reported that goat milk soap was stable for 30 days of storage. Plant-based soaps generally exhibit longer shelf-life primarily due to the fatty acid profile of the plant oils used. Oils rich in saturated fatty acids such as coconut and palm oil (high in lauric and palmitic acids, respectively) confer hardness and oxidative stability, prolonging the bar soap's longevity (Arias *et al*., 2023; Cermeño *et al*., 2024).

3.6.8 Antimicrobial activity

Antibacterial activity refers to the ability of a soap to prevent bacterial growth. Milk-enriched soaps have been reported to show a significant antibacterial activity against various skin pathogens. According to Sharaf *et al*., (2016) goat milk soap has a significant antibacterial activity against bacteria which are attributed to skin infections and acne such as *Staphylococcus aureus* and *Propionibacterium acnes* . The antimicrobial activity is associated to the bioactive compounds such as enzymes, proteins and vitamins which are naturally present in goat milk (Chasanah *et al*., 2022). Soap containing 5% cow milk was found to have strong antibacterial activity against *S. aureus* (Cosentino *et al*., 2018). On the hand, soaps formulated with phytochemicals from plants such as aloe vera and neem also show strong antimicrobial activities (Khan *et al*., 2025). The herbal soaps have been found to inhibit the growth of both gram-positive bacteria, such as *S. aureus* and *S. epidermidis* and to some extent gram-negative bacteria like *Escherichia coli* (Igbeneghu, 2013). The efficacy of botanical soaps largely depends on the nature and concentration of bioactive phytochemicals such polyphenols and essential oils (Narayana *et al*., 2024). Therefore, both milk and plant-based soaps demonstrate significant antibacterial properties hence underlines their value in toiletries formulations.

3.6.9 Sensory acceptability of milk-enriched soap and plant -based soaps

Sensory attributes are vital parameters that influence the consumer preference and commercial success of soap products (Wira *et al*., 2023). The appearance, scent, feel, and performance of a soap significantly shape consumer responses. In the soap industry, these sensory qualities like color, scent, lather, texture, and skin sensation after use can make or break a product (Parente & Ares, 2021). When users enjoy these aspects, they're more likely to stick with the brand, making sensory appeal a key factor in customer preference and product success.

Consumers often associate milk-based soaps with gentleness and skin moisturizing benefits. There *et al.*(2022), reported that goat milk soap produces a soft bar that moisturizes the skin, making it suitable for individuals with dry skin. Similarly, cow milk soaps are known for their mildness and skin compatibility (Susanti *et al.*, 2018). Additionally, camel milk has emerged as a potential ingredient for antibacterial bath soap, supported by the studies on its unique composition of bioactive compounds (Yaseen & Hanee, 2019).

In comparison, plant-based soaps formulated with oils such as coconut, palm, olive offer distinct sensory qualities. Palm and coconut oils are rich in shorter chain (C8-C14) saturated fatty acids, with coconut containing approximately 54.06% lauric acid and palm oil containing 45.0% palmitic acid (Arias *et al.*, 2023). According to Putri *et al.* (2023) coconut oil, a rich source of lauric acid produce soap with an excellent lathering and cleansing ability while olive oil has oleic acid which promotes a denser, creamier lather with a smooth feel. The foamability of plant based bar soaps is determined by the plant oils used in the formulation (Cermeño *et al.*, 2024). The consumer acceptability for both types of soaps is tied to personal sensory attributes such as color, scent and foamability (Parente & Ares, 2021). Optimizing these sensory attributes is essential to satisfy diverse consumer preferences and to maintain competitiveness in the market.

3.7 Conclusion

The formulation, composition, and skin benefits of plant-based and milk-enriched soaps have been compared in this study. Despite having very different fatty acid profiles, bioactive compounds, and physicochemical characteristics, both types of soap exhibit good cleansing and dermatological functionality. Because of their high protein, lactic acid, vitamins, minerals, and lipid content, milk-based soaps provide excellent moisturization, gentle exfoliation, and skin-renewing qualities, making them ideal for dry or sensitive skin. On the other hand, plant-based soaps made from herbal extracts and unsaturated oils have stronger antibacterial and antioxidant properties, a firmer texture, and increased oxidative stability. Growing interest in natural and functional skincare is highlighted by innovations in both categories, such as green extraction in plant-based formulations and probiotic enrichment in milk soaps. Eventually, understanding these differences is essential for guiding formulation strategies, consumer choices, and future research in cosmetic science.

CHAPTER FOUR

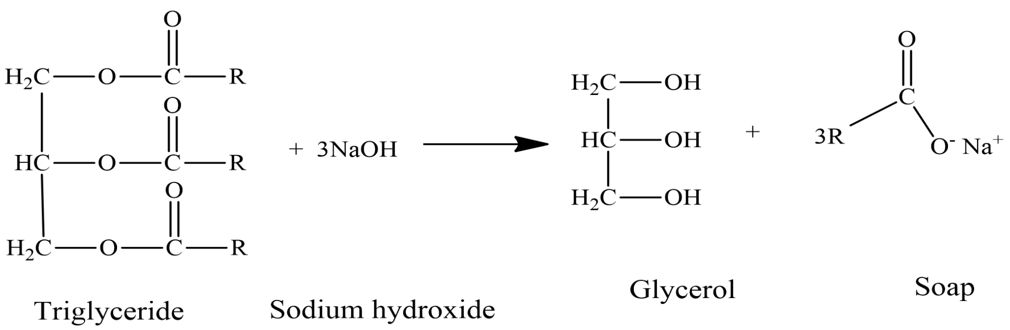
Formulation and Physicochemical Characterization of Antibacterial Camel Milk Cream-Based Bath Soap

Abstract

Bath soap is primarily used for skincare and body cleansing, playing a vital role in maintaining personal hygiene and reducing infections caused by pathogenic microorganisms. The demand for natural skincare products has led to increased interest in milk-derived ingredients due to their moisturizing and therapeutic properties. This study focused on evaluation of physicochemical properties, shelf -life, antibacterial efficacy, and sensory evaluation of camel milk cream-based bath soap. Bath soaps were produced using the cold saponification process using camel milk cream, palm oil, and coconut oil as primary ingredients. Fresh camel milk and cream were subjected to compositional and quality analyses, including density (Lactometer), fat content (Gerber method), and protein content (Kjeldahl method). The saponification reaction and resultant soap formulations were further analysed using Fourier Transform Infrared Spectroscopy (FTIR) to monitor functional group changes and confirm reaction completion. The formulated soaps were characterized for physicochemical properties such as pH (multiparameter pH meter), total fatty matter (gravimetric method), moisture content (oven-drying at 110 °C), foam stability (cylinder shake test), hardness (cone penetrometer) and alkali content (acid–base titration). Shelf-life was evaluated over 8 weeks by monitoring pH, alkali content, and total fatty matter. Antibacterial activity against *S. aureus* and *E. coli* was determined using the agar well diffusion method, with inhibition zones analysed by Duncan's multiple range Test ($p < 0.05$). Sensory evaluation was performed with 20 untrained panellists aged 18 – 37 years under controlled conditions to assess formability, skin feel, moisturizing, odour, texture, hardness and overall acceptability. The results were as follows; density of 1.031 g/cm^3, fat content of 43.33 ± 0.58%, and protein content of 1.94 ± 0.07%, respectively. FTIR confirmed complete saponification by the disappearance of ester carbonyl (C=O) at 1742 cm^{-1} and the appearance of carboxylate (COO^-) at 1554 and 1408 cm^{-1}, with amide bands at 1649 and 1465 cm^{-1} indicating proteins from camel milk cream. The soaps showed pH (10.17 – 11.51), total fatty matter (45.19 – 66.43%), moisture (21.06 – 33.40%), foam stability (0.33 – 1.37 cm), hardness (0.281 – 0.639 kPa), and acceptable alkali content. Over 8 weeks, the soaps retained stable physicochemical and organoleptic properties, with only slight moisture loss. Formulations with higher camel milk cream exhibited significantly greater antibacterial activity ($p < 0.05$) against *S. aureus* and *E. coli*. Sensory evaluation by 20 untrained panellists indicated high acceptability, especially for skin-smoothing and moisturizing effects. The formulation with 20% coconut oil and 20% camel milk cream achieved balanced physicochemical and antibacterial properties comparable to Dettol. These results suggest that camel milk cream-based soap is a promising natural alternative to conventional antibacterial soaps, offering both effective cleansing and enhanced skincare benefits.

4.1 Introduction

Bath soaps play a fundamental role in personal hygiene by removing dirt, oil, and microorganisms from the skin (Mihalache *et al.*, 2021). The increasing consumer demand for natural and skin-friendly cosmetic products - valued at approximately US$186 billion globally has driven research into alternative ingredients such as plant oils, animal fats, and milk derivatives (Schneider *et al.*, 2001). Soaps in which vegetable/ plant oils or animal fats are the base materials and infused with organic additives and fragrances are described as natural soaps (Kanyama *et al.*, 2025). Natural soaps are typically formulated through cold saponification of fats and oils using an alkali, resulting in products with varying physicochemical and dermatological properties depending on the raw materials used (Owoicho, 2021). In the saponification reaction, either the animal fats or vegetable oils is hydrolysed into glycerol and fatty acids by the alkali (Mwanza & Zombe, 2020).The fatty acids formed then combine with the alkali forming soap as shown in the equation 4.1 below.



(4.1)

Cold saponification process depends on the heat produced from the exothermic reaction of the fatty acids present in the melted animal fats/ plant oils to facilitate the process (Vidal *et al.*, 2018).

The physicochemical properties of soap entirely depend on the chemical compositions and the nature of fats and oils used in making soap and the type of alkali used. Sodium hydroxide produces hard soap while potassium hydroxide makes soft soap particularly liquid soap (Alum & Nnchi, 2024). Additionally, saturated fatty acids produces hard soap with high foamability while unsaturated fatty acids produces soap with high moisturizing and skin nourishment effects (Kuntom *et al*., 1996). Palm, olive and coconut oils are commonly used in making natural bath soaps (Putri, 2023). In some cases, animal fats or ruminants' milk are blended with palm and coconut oils to produce soap with balanced qualities and good performance (Uduma *et al*., 2025). In soap formulations containing a blend of coconut oil and palm oil, milk is often incorporated to enhance the overall quality of the soap (Murti *et al.*, 2024). Palm and coconut oils are rich in shorter chain (C8-C14) saturated fatty acids, with coconut containing 54.06% lauric acid and palm oil containing 45.0% palmitic acid (Arias *et al*., 2023). This means that palm or coconut oils soap have high foamability due to enhanced solubility of saturated fatty acids in water.

Camel milk cream has been identified as a potential ingredient in soap formulation, attributed to its unique chemical composition rich in bioactive compounds such as proteins, fatty acids, and vitamins (Arain *et al*., 2023). Camel milk cream is rich in saturated and unsaturated fatty acids, bioactive proteins, and moisturizing agents like lanolin, provides beneficial properties such as skin hydration, antibacterial activity, and anti-aging effects (Arain *et al*., 2023). Mohamed and Ayman .(2016), reported that camel milk contains 63.8% saturated fatty acids, 34.4% monounsaturated fatty acids (MUFA) and 1.8% polyunsaturated fatty acids (PUFA).

In addition, camel milk is a very promising therapeutic ingredient in the formulation of bath soap (Mehta & Agrawal, 2020), it is rich in alpha-hydroxyl acids, which exfoliate dead cells on the skin; essential proteins such as lactoferrin and immunoglobulins, which have anti-bacterial and anti-fungal properties, lanolin which moisturizes the skin and liposomes, which have anti-ageing effects (Jilo & Tegegne, 2016). These potential health benefits and therapeutic properties can be harnessed by formulating bath soap using camel milk cream.

Many studies on soap formulation have focused on the use of cow milk, goat milk, and plant-based oils such as palm and coconut oils as main ingredients (Susanti *et al*., 2018). Although camel milk cream has recognized potential, little research has explored its use in soap formulations, unlike cow and goat milk, which have been more extensively studied.

This study addresses this gap by formulating bath soaps using varying concentrations of camel milk cream - with palm oil and coconut oil - and evaluating their physicochemical properties, antibacterial activity, and consumer acceptability. Other physicochemical parameters evaluated include; moisture content, foam stability, pH, hardness, alkali content, total fatty content, shelf-life and sensory acceptability of consumers. The objective was to determine the optimal formulation that balances cleansing performance, skin-friendliness, and therapeutic benefits, thereby contributing to the development of natural and functional skincare products.

4.2 Materials and Methods

4.2.1 Sample collection

Fresh *Camelus dromedarius* milk sample was purchased from Ngamia Milk Suppliers in Nanyuki, Laikipia County, Kenya. The fresh *Camelus dromedarius* milk was stored in sterile containers and transported in a cold box at 4 ^{o}C to the Food Science Laboratory at Meru University of Science and Technology. Refined palm oil and coconut oil were sourced from certified local suppliers. Analytical grade sodium hydroxide (NaOH), sodium chloride (NaCl), sulfuric acid (H_2SO_4), isoamyl alcohol, and nitric acid were obtained from Sigma-Aldrich Darmstadt, Germany.

4.2.2 Sample preparation and characterization

a) Milk thermal stability test

Milk thermal stability test was conducted to as per the method describe by Waikar and Terde, (2023). Milk stability was done to determine the stability of milk proteins using the alcohol test and assess its suitability for processing. First, well-mixed sample of fresh milk was collected in a 20ml beaker, ensuring that foam or the cream layer was avoided. An analytical grade ethanol solution, 65% concentration, was freshly prepared as the reagent. The gun was loaded with freshly prepared 65% alcohol solution. Using the loaded alcohol gun, a sample of 1ml was scooped into the second slot of the gun, after which the contents were gently mixed by tilting and observations made.

b) Milk density measurements

Milk density is a key quality parameter that reflects its composition, processing suitability, and compliance with standards (Oselu *et al*., 2022). Density test was performed using lactometer. A sample of 50mL fresh milk was transferred into a 100mL measuring cylinder at room temperature. A lactometer was carefully immersed into the measuring cylinder containing the sample milk and the density readings recorded.

4.2.3 Milk cream extraction using centrifugation method

The camel milk cream extraction was done in order to obtain the fat-rich cream from the skimmed milk. The fresh camel milk was separated into skimmed milk and cream using disc and bowl centrifugation (Armfield, UK) following the method described by Rocco *et al*. (2021) with modifications. In a stainless aluminium pan, 20L of fresh milk was transferred and heated to 50 ^{o}C in a water bath. The centrifuge discs and bowl were cleaned with distilled water and sterilized with more distilled water at 100 ^{o}C and assembled. Using a graduated jug, 20L of milk was transferred gradually while centrifugation process was carried at 1500 rpm. Cream was separated and collected in a graduated jug. The separated cream was then pasteurized at 80 °C for 30 minutes and cooled to 40 °C to ensure its microbial safety during storage. The cream was stored in a refrigerator at 4 °C for subsequent procedures.

4.2.4 Characterization of camel milk cream

a) Fat determination

Fat content was determined using the Garber method according to Kleyn (2001), involving sulfuric acid digestion and centrifugation. The camel milk cream test sample was prepared by placing 1g of the sample in a test tube and heated in a water bath at 39 °C for 20 seconds, followed by thorough mixing through 10 inversions. Ten millilitres of sulfuric (VI) acid at 15 °C was added into the butyrometer. The butyrometer containing sulfuric (VI) acid was tared, and 11.13 g of the tempered camel milk cream sample was slowly added to prevent charring and a violent reaction with the acid. One millilitre of isoamyl alcohol was then added to the butyrometer containing the test sample.

The butyrometers were placed in a centrifuge and centrifuged for 4 minutes. After centrifugation, they were immersed in a water bath at 60°C for 5 minutes to allow the fat column to equilibrate. A butyrometer was removed from the water bath, dried, and the upper and lower menisci of the fat column were recorded; their difference was used to determine fat content.

b) Protein determination

The protein content in camel milk cream was analysed by the Kjeldahl method, with some modifications as described by AOAC (1994) using a digestion system (Kjeltec 8400, FOSS, Denmark). Five grams of cream sample was weighed into a pre-folded, tared filter paper to four decimal places. The filter paper was then folded and placed in the Kjeldahl test tube containing 3.5 g potassium sulphate (K_2SO_4), 0.105 g copper (II) sulphate pentahydrate ($CuSO_4 \cdot 5H_2O$), and 0.105 g titanium (IV) oxide (TiO_2) followed by the addition of 20 mL of 98% (18.4 M) sulfuric acid. Blanks were prepared with all the chemicals and filter paper but without the sample. The samples were digested together with the blanks at 420 °C until a light-green colour was observed. The digester was then turned off and allowed to cool to 60 °C. Subsequently, 50 mL of distilled water was added to the cooled digested solution.

The water condenser was then turned on, followed by the addition of 50 mL of H_3BO_3 solution into a 500 mL graduated Erlenmeyer titration flask. The flask was placed under the condenser tip, ensuring that the tip remained below the surface of the boric acid solution. A total of 75 mL of 50% NaOH was added at the sidewall of the Kjeldahl flask without agitation. The flask was then connected to the distillation condenser, and its contents were vigorously swirled and mixed as heating continued until all the NH_3 was distilled and 150 mL of the distillate was collected. The collecting flask was then lowered to allow the drainage of the last drops from the condenser tip.

The distillate was titrated against 0.1N HCl solution until the first traces of pink color appeared. The volume of HCl used was recorded. The nitrogen content was calculated using the formula:

$$YI = \frac{14.007 \times (V_a - V_b) \times M}{W} \quad (4.2)$$

(Where V_a and V_b represent the mL of HCl used for the test portion and black, respectively; M is the molarity of the HCl solution and W is the weight of the sample.

The percentage of protein was determined by multiplying the nitrogen percentage by 6.38 as per the method described by Magomya *et al* (2014).

4.3 Formulation Optimization and Preparation of Soap Samples

4.3.1 Procedure for the optimization formulation of soap samples (F1 to F11)

To determine the ratio of palm oil and coconut oil that would yield a soap with an optimal balance of key physicochemical parameters including pH, percentage alkali content, and total fatty matte, eleven soap formulations (F1–F11) were prepared by varying the proportions of palm oil and coconut oil as per the optimisation method described by Zunita (2025), with minor modifications. Camel milk cream was subsequently incorporated into the formulation, as shown in Table 4.2.

In general, samples of palm oil and coconut oil were weighed in separate 250 mL beakers. NaOH (98%) and distilled water were also weighed in separate beakers. The two oils were first mixed in one beaker and heated to 40 ^{o}C. NaOH and water were mixed in a 1:3 ratio to prepare a lye solution which was then cooled to 40 ^{o}C and aliquots of it added slowly to the oil blend while stirring. NaCl (1g) was subsequently added to the blend while stirring continues until a thick paste is obtained.

The paste of soap was transferred into moulds measuring 10.4 x 2.8 x 4.9 cm and allowed to dry in open air at room temperature for 24 hours for complete saponification reaction. The soap was then allowed to cure at room temperature for 7 days to allow any excess water to evaporate. In order to obtain 11 different formulations used in the optimization process, various oil ratios were used with equal amounts of NaOH and water in the ratio of 1:3 by mass respectively.

Table 4.1:

Optimization Procedure for soap formulation of palm oil and coconut oil blend soap

Composition in grams (%) per 160g of soap				
Soap Sample	**Palm Oil**	**Coconut oil**	**NaOH**	**Water**
F1	100 (62.5%)	0 (0%)	15	45
F2	90 (56.25%)	10 (6.25%)	15	45
F3	80 (50%)	20 (12.5%)	15	45
F4	70 (43.75%)	30 (18.75%)	15	45
F5	60 (37.5%)	40 (25%)	15	45
F6	50 (31.25%)	50 (31.25%)	15	45
F7	40 (25%)	60 (37.5%)	15	45
F8	30 (18.75%)	70 (43.75%)	15	45
F9	20 (12.5%)	80 (50%)	15	45
F10	10 (6.25%)	90 (56.25%)	15	45
F11	0 (0%)	100 (62.5%)	15	45

Source: *Researcher (2024)*

4.3.2 Procedure for the preparation of camel milk cream-based soap samples (F5 to F5d)

Camel’s milk cream bath soap was formulated using cold saponification process as per the method described by Selladurai and Kathiresapillai, (2019) with slight modifications as shown in Table 4.2.

Table 4.2:

Ingredients for camel milk cream soap formulation

	Composition in grams (%) per 160g of soap				
Ingredients	**F5(Control)**	**F5a**	**F5b**	**F5c**	**F5d**
Camel Milk Cream	0 (0%)	10 (6.25%)	20 (12.5%)	30 (18.75%)	40 (25.0%)
Coconut Oil	40 (25.0%)	30 (18.75%)	20 (12.5%)	10 (6.25%)	0 (0%)
Palm Oil	60	60	60	60	60
NaOH	15	15	15	15	15
H_2O	45	45	45	45	45

Source: *Researcher (2024)*

Samples of palm oil and coconut oil were weighed in separate 250 mL beakers. NaOH (98%) and distilled water were also weighed in separate beakers. The two oils were first mixed in one beaker and heated to 40 ^{o}C. NaOH and water were mixed in a 1:3 ratio to prepare a lye solution which was then cooled to 40 ^{o}C and aliquots of it added slowly to the oil blend while stirring. NaCl (1g) was subsequently added to the blend while stirring continues until a thick paste is obtained. The paste of soap was transferred into moulds measuring 10.4 x 2.8 x 4.9 cm and allowed to dry in open air at room temperature for 24 hours for complete saponification reaction. The soap was then allowed to cure at room temperature for 7 days to allow any excess water to evaporate. The procedure was repeated by incorporating camel milk cream at concentrations of 0%, 10%, 20%, 30%, and 40% w/w to produce soaps samples F5, F5a, F5b, F5c and F5d, respectively.

4.4 Saponification reaction analysis by FTIR

Complete saponification reaction of alkali and oils was evaluated using FTIR-ATR (QATR-S) instrument in the 4000-400 cm^{-1} with a resolution of 4cm^{-1}. The camel milk cream, palm oil, coconut oil and a soap containing coconut oil, palm oil and camel milk cream were placed on the ATR sample holder and the transmittance recorded with a range of 1 cm^{-1}.

4.5 Evaluation of Physicochemical Parameter of the Formulated Soap

Several physicochemical parameters were evaluated for quality assessment of the formulated soaps. Physicochemical parameters were compared with the commercial soap (Imperial lather soap) as standard.

4.5.1 Moisture content

The moisture content of the formulated soap samples was determined using the oven-drying method described by Vivian *et al.* (2014), with minor modifications. A clean, dry crucible was weighed using an analytical balance (CP313) (sensitivity: 0.1 mg), and its mass recorded. Five grams of the soap sample was then accurately weighed into the crucible, and the combined mass recorded. The crucible containing the sample was placed in a hot-air oven at 110 °C for 2 hours to dry.

After drying, the crucible was transferred to a desiccator containing silica and allowed to cool for 48 hours to achieve a constant mass. The crucible was then reweighed, and the moisture content (%) of the sample determined using the formula:

$$Moisture\,(\%) = \frac{Weight\ loss}{Weight\ of\ sanple} \times 100 \qquad (4.3)$$

4.5.2 Foam stability

The foam stability test was carried out as per the method described (There *et al*., 2022). According to this method, 1 g of the formulated soap was dissolved in 10 mL of distilled water. The mixture was then heated at 70 °C to increase solubility. Then 3 mL of the resulting solution were placed in a 50 mL measuring cylinder, followed by the addition of 3 mL of distilled water. The mixture was shaken for 20 seconds, and the height of the foam column was recorded. This measurement was repeated after 15 minutes to assess foam stability.

4.5.3 Alkalinity/Acidity

Potential of hydrogen (pH) measurements were carried out using a multiparameter pH meter (MK900-CN), which was calibrated before use according to the manufacturer's instructions and following the procedure by Tarun *et al*.(2014). Calibration was performed using standard buffer solutions (pH 4.00, 7.00, and 10.00) at room temperature to ensure accuracy. One gram of the soap sample was dissolved in 100 milliliters of distilled water, heated to 70 °C, and stirred until the soap sample dissolves completely. The solution was cooled in an ice bath to 40 °C, after which the pH meter electrode was immersed in the solution and allowed to stabilize. Once a stable reading was obtained, the pH was recorded. This procedure was repeated twice more, and the mean pH value was calculated.

4.5.4 Soap hardness

Soap hardness was determined using a cone penetrometer, following the method described by (Yarovoy & Post, 2016). In this method, a cone was driven into the soap samples, and the force at which the cone penetration ceased was measured. This force value was recorded and used to quantify the hardness of the soap.

$$H = \frac{W}{A_c} = \frac{W}{\pi d^2 \tan^2 \alpha} \qquad (4.4)$$

where W is the total load (weight) that causes the deformation, and A_c *is the contact area, which is expressed in terms of the depth d and angle α of the cone.*

4.5.5 Total fatty matter

The total fatty content was determined using the method outlined by There *et al*. (2022), with few modifications. A 10 g sample of the soap was added to 100 ml of distilled water, preheated to 70 °C, in a 250 ml beaker and stirred thoroughly until the soap dissolved. Then 100 ml of diluted sulfuric acid (1:1) was added to the beaker, and the mixture was heated until a distinct layer of fatty acids separated. One gram of sodium chloride was then added to the solution, which was allowed to cool to room temperature. The aqueous acid layer was carefully removed using a separating funnel, leaving the fatty layer in the funnel. To the fatty layer, 150 ml of ethyl ether was added to extract the fatty acids. The ethyl ether was evaporated from the resulting mixture using a boiling water bath. The remaining content was dried in an air oven in a pre-weighed crucible at 105 °C for 30 minutes. The samples were cooled in a desiccator and then weighed.

The total fatty content was calculated using the following equation:

$$\text{Total fat matter (\%) by mass} = \frac{(Y\text{-}X)}{Z} \times 100 \qquad (4.5)$$

Where Y = mass in grams of the crucible and fatty matter after drying, X = mass in grams of the crucible and Z = mass in grams of the soap sample

4.5.6 Alkali content

Alkali content was carried out as per the method described (Betsy *et al.*, 2021). In this method, 5 g of soap sample was dissolved in 100 ml of hot water. 40 ml of 0.5 N HNO_3 was added to acidify the solution. The mixture was heated until the fatty acids separated and formed a distinct layer on the surface of the solution. This layer was then cooled in ice water to solidify the fatty acids, which were subsequently isolated. The remaining aqueous solution was treated with 50 ml of chloroform to remove any residual fatty acids. The aqueous phase was then measured, and a 10 ml aliquot was titrated against 0.5 N NaOH with methyl orange as an indicator. Using the titre value obtained, the total alkali content was calculated according to the formula.

Total volume of the aqueous solution V= X ml

10 ml of aqueous solution required t ml of NaOH

Volume (ml) of aqueous solution requires $A = \frac{V \times t}{10} = A\ ml$ (4.6)

Amount of NaOH required by acid in aqueous solution =A ml

Volume (ml) of HNO_3 required $B = \frac{A \times Normality\ of\ NaOH}{Normality\ of\ HNO_3}$

Volume of HNO_3 required for neutralizing NaOH = C=40 – B

Amount (g) of NaOH in 1000 cm^3 of soap solution (E) = $\frac{C \times 40 \times Normality\ of\ HNO_3}{!000}$

250 cm^3 of soap solution contains $F = \frac{E \times 250}{1000}$

4.6 Soap Shelf-life Stability

Formulated soap samples were stored at room temperature for 8 weeks to assess its stability. During this time, measurements of moisture content and hardness were taken periodically to determine the percentage of moisture and hardness as time progressed.

4.7 Anti-microbial Activity

The antibacterial efficacy of the formulated soap was tested against *Staphylococcus aureus* (ATCC 25923) and *Escherichia coli* (ATCC 25922) using the well diffusion method on Mueller-Hinton agar (Mwambete & Lyombe, 2011) with some modifications where six samples were tested for antimicrobial activity. Soap extracts at concentrations of 2, 4, 6, 8, 10, and 12 mg/mL were tested. F5 soap without camel milk cream was used as a negative control and the four soaps (F5a, F5b. F5c, F5d). A commercially available and widely marketed antibacterial soap (Dettol soap) was used for comparative analysis.

A 100 mg/mL stock solution of each soap sample was prepared by dissolving 0.5 g of soap in 5 mL of sterile distilled water. From this stock, serial dilutions were prepared in Eppendorf tubes to obtain final concentrations of 2, 4, 6, 8, 10, and 12 mg/mL. Specifically, 20 µL of the stock solution was mixed with 980 µL of sterile distilled water to obtain 2 mg/mL; 40 µL of stock solution was mixed with 960 µL of sterile distilled water to obtain 4 mg/mL; 60 µL of stock solution was mixed with 940 µL of sterile distilled water to obtain 6 mg/mL; 80 µL of stock solution was mixed with 920 µL of sterile distilled water to obtain 8 mg/mL; 100 µL of stock solution was mixed with 900 µL of sterile distilled water to obtain 10 mg/mL; and 120 µL of stock solution was mixed with 880 µL of sterile distilled water to obtain 12 mg/mL. All solutions were shaken gently to ensure uninform mixing before analysis. Suspensions of pure cultures of *E. coli* (ATCC 25922) and *S. aureus* (ATCC25923) were prepared and standardized with 0.5 McFarland standard suspension. 0.1 ml of each suspension was aseptically inoculated in sterile agar plates containing Mueller-Hinton Media (Himedia reference:24756) using spread plate method. Each agar plate was divided into four portions where 4.8 mm diameter well was aseptically punched using a sterile cork-borer in each portion.

Into three of the four wells, 20 µl aliquot of the formulated constituted soap sample suspension was deposited, three wells for triplicate measurements and 20 µl of sterile distilled water into the fourth well as a negative control. Himedia antimicrobial discs reference (OD215R-100NO) containing 8 antibiotic discs (ampicillin, tetracycline, co-trimoxazole, kanamycin, chloramphenicol, gentamicin and sulphamethoxazole) were also incorporated as positive controls. This procedure was repeated for all the three concentrations of each sample. The plates were incubated at 37 °C for 18 - 24 hours. The diameters of the zones of inhibition were measured using digital vernier callipers and recorded in mm.

4.8 Sensory Evaluation on Acceptability of Bath Soap

Sensory evaluation was carried out using a modified hedonic test method (Kowalska *et al.*, 2017; Mayangsari, 2022; Wira *et al.*, 2023). For sensory descriptive analysis, a panel of 10–20 untrained assessors are considered sufficient (Losó *et al.*, 2012). In this study, twenty untrained panelists (12 females and 8 males) aged 18–37 years participated in the hedonic test. The participants were drawn from students and staff population at Meru

University of Science and Technology based on the criteria such as willingness to participate, being physically and mentally healthy (not colour blind, free from olfactory and psychological disorders), non-smokers and not using perfume during the test. The hedonic test was modified to enhance reliability and minimise bias. The soaps from each treatment (F5, F5a, F5b, F5c, F5d and Imperial) were coded with four letters as (ABCD, ABDC, ACBD, ACDB, ADBC and ADCB) respectively, to hide their identity to the panellists. Panellists were requested to follow the instructions as provided in the sensory evaluation questionnaire in appendix II. Attributes assessed included foamability, texture, odour, moisturizing effect, hardness, and skin irritation using a 9-point scale (1 = dislike extremely; 9 = like extremely), and then rated the overall acceptability of each soap sample.

4.9 Statistics Analysis

Measurements were performed in triplicate, and the mean values were calculated. Data on antibacterial activity were analyzed using one-way ANOVA at a significance level of $P < 0.05$ with SPSS (version 26). The data on physicochemical parameters (pH, moisture content, total fatty matter, foam stability and hardness), shelf life, and sensory evaluation were analyzed using OriginPro 8 software by performing descriptive statistics (mean ± standard deviation) and trend analysis to determine changes over time.

4.10 Ethical Consideration

All panelists participated voluntarily in the sensory evaluation and provided informed written consent prior to participation. They were clearly informed of their right to withdraw from the study at any stage without any consequences.

4.11 Results and Discussion

4.11.1 Milk thermal stability

Milk thermal stability measurements were carried out to determine the stability of milk proteins using the alcohol test and assess its suitability for processing. The mixture remained smooth and uniform, with no visible clots or flakes. This suggests that the milk was of good quality and would not coagulate on thermal processing. When unstable milk is mixed with ethanol (65%), the mixture shows immediate or delayed coagulation/flocculation due to changes in the ionic balance between casein and calcium salts (Waikar & Terde, 2023).

4.11.2 Milk density

Milk density was measured to ascertain its quality, to detect if there was any adulteration by adding water or removing cream. Camel milk recorded a density of 1.03g/cm^3. The finding was within the range of 1.02 to 1.031 g/cm^3 reported by Karaman *et al*. (2022).

4.11.3 Cream fat and protein content

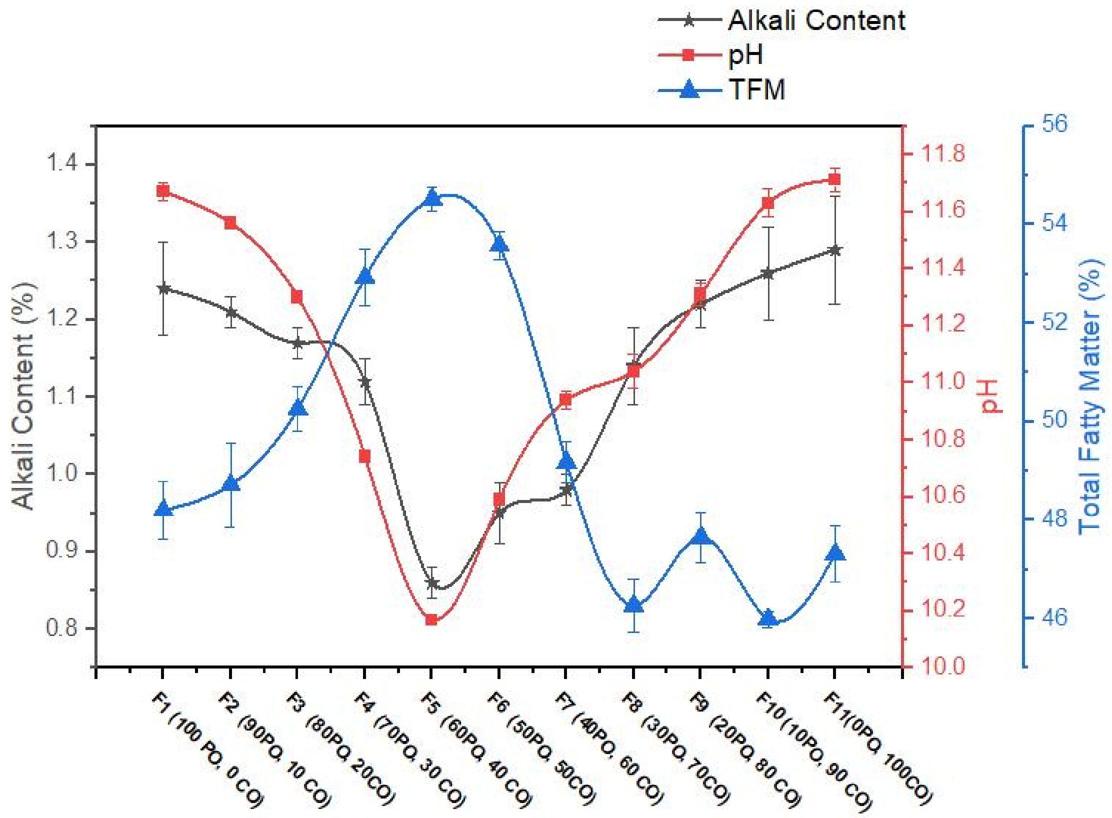
Camel milk cream recorded a mean fat content of 43.33 ± 0.58%, which was considerably higher than the 3.28 ± 0.48% reported for whole camel milk by Karaman *et al*. (2022). In contrast, the protein content of camel milk cream was 1.94 ± 0.07%, lower than the 2.70 –3.40% reported for whole camel milk by Karaman *et al*., (2022).These differences may be attributed to variations in camel milk's chemical composition arising from factors such as age, geographical location, feeding conditions and analytical techniques (Rahmeh et al., 2019). The protein content for camel milk cream was found to be 1.94 ±0.07 % . Karaman *et al*., (2022) reported protein content of 2.70 - 3.40 % for whole camel milk. The protein content was low compared to that of camel milk and this may be attributed to whey protein that remained in the skimmed milk during cream separation (Hukavčeva & Brezovečki, 2015).

4.11.4 pH, TFM and Alkali Content of Palm Oil and Coconut Oil Soap Blend

Figure 4.1 shows the effects of varying palm oil and coconut oil ratios on pH, alkali content and fatty matter on the soap. Both pH and percentage alkali content decrease gradually from F1 (100% PO) to F11 (100% CO) up to F5 which contains 60% PO and 40% CO. F5 exhibited the highest total fatty matter (54.51%) with correspondingly lower pH and free alkali. This effect is attributed to the optimized proportions of palm and coconut oils in the F5 formulation, which yielded a triglyceride matrix combining short-chain lauric and long-chain palmitic fatty acids. Palm oil is rich in long chain palmitic acids, whereas coconut oil is rich in short chain lauric with higher saponification values (Suryani *et al*., 2020). Blending these oils enhances reaction kinetics and reduces fatty-acid loss, producing a mixed sodium carboxylate matrix of varied chain lengths that retains more.

Figure 4.1:

Physicochemical properties of palm oil and coconut oil soap blend



Source: *Researcher (2024)*

These findings are in close agreement with the findings obtained by Selladurai and Kathiresapillai (2019) which found that nature and ratio of oils significantly affect soap physicochemical parameters. Additionally, Zunita. (2025), reported 60:40 ratio for the soap formulated from palm oil and coconut oil as ratio that produces a quality soap with balanced physicochemical parameters.

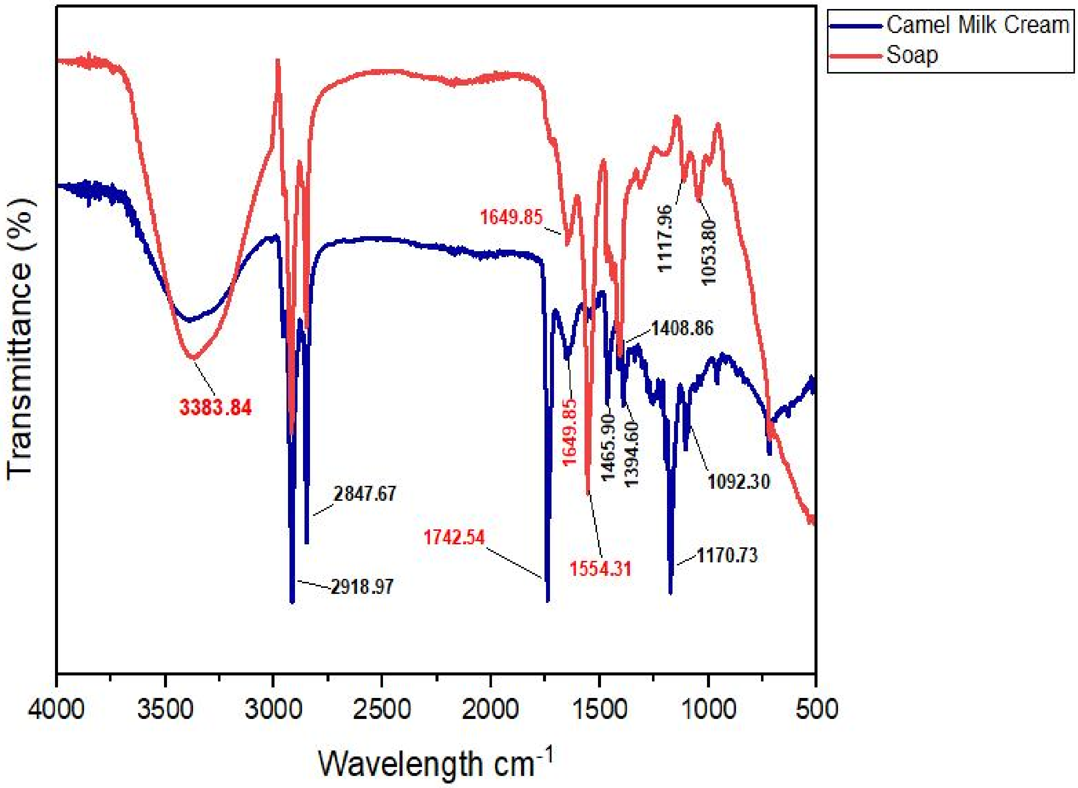
4.11.5 FTIR Spectroscopic Analysis of the Saponification Reaction

The camel milk cream and camel milk cream soap characterized by FTIR are presented in figure 4.2 FTIR spectra confirmed that camel milk cream was successfully saponified into soap. In the starting material (camel milk cream), a strong absorption observed at 1742.54 cm^{-1} associated to the C=O stretching vibration of the ester group (–C(=O)O–)

present in triglycerides (Wu *et al*., 2001). Additional peaks at 2918.97 cm^{-1} and 2847.67 cm^{-1} are due to C–H stretching vibrations characteristic of long hydrocarbon chains weak absorptions at 1649.85 cm^{-1} region is assigned to Amide I (Eid et al., 2022).

Figure 4.2:

FTIR spectra for camel milk cream and camel milk cream soap



Source: *Researcher (2025)*

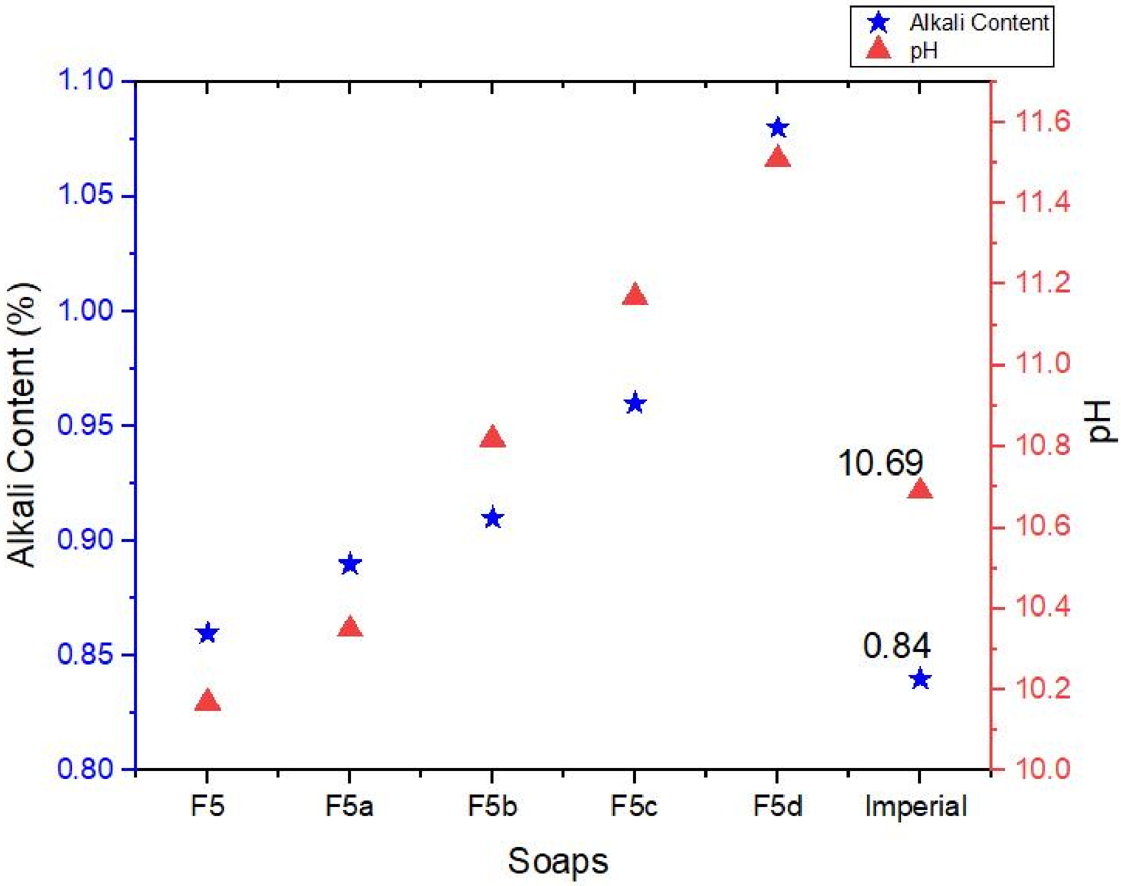
After saponification reaction, changes were observed in the spectrum soap. The ester C=O band at 1742.54 cm^{-1} disappeared completely, confirming cleavage of the ester bonds in the triglycerides the key chemical step in saponification. As a result, new peaks observed at 1554.31 cm^{-1} and 1408.86 cm^{-1} are associated to asymmetric and symmetric stretching vibrations of the carboxylate ion (R−COONa) (Rohman & Yaakob, 2011). A broad band observed at 3383.84 cm^{-1}, is attributed to N–H stretching (Eid et al., 2022). Absorption band observed at 1649.85 cm^{-1} correspond to C=O of amide I of proteins while absorption band at 1465.90 cm^{-1} associated to N-H bending and C-N stretch of amide II Sadat and Joye, (2020),relate amide I band and C-N stretching vibrations to absorption regions of (1600-1700 cm^{-1}) and (1410-1500 cm^{-1}). This then suggest the proteinaceous ingredients from the camel milk cream which attribute to the moisturizing and skin-conditioning properties of the final soap product.

4.11.6 Effect of Camel Milk Cream on pH and Alkali Content

The percentage alkali content and pH increased with an increase in camel milk cream in the formulation (Figure 4.3). The pH value and percentage of alkali content increases from F5 to F5d with an increase in camel milk cream. F5 and F5a had a pH of 10.17 and 10.35 which were below the standard soap. F5b had a pH of 10.82, slightly above the standard soap while F5c and F5d had a pH of 11.17 and 11.51 respectively. The pH value of a healthy skin ranges from 4.1 to 5.8 (Proksch, 2018). Skincare products are therefore expected to have pH values that are close to the range to reduce skin irritation. The pH values of the formulated camel milk cream soaps were not within the range of healthy skin pH but were closer to those of the control soap (Imperial Leather), which is approved by the regulatory bodies like Kenya Bureau of Standards (KEBS) and has no reported cases of skin irritation related to pH (Idoko *et al*., 2018; Vivian *et al*., 2014). Incomplete hydrolysis during the saponification process may be attributed to high pH values by F5c and F5d (Abba *et al*., 2021).

Figure 4.3:

Effect of camel milk cream on pH and alkali content



Source: *Researcher (2024)*

The pH values for F5, F5a and F5b were found to be within the range of the pH values obtained by Habib *et al*., (2016) for commercial bath soaps in Bangladeshi market. Similarly, Murti *et al*. (2024), reported a pH value of 11.40 ± 0.44 for bar soap formulated using goat milk cream, which was accepted for human skin use. The pH values for the formulated soaps F5, F5a, F5b were within the Kenya Bureau of Standards limit of 9-11 while F5c and F5d were slightly above the limit (Kenya Bureau of Standards, 2021).

With regards to percentage alkali content, there is increase with an increase in camel milk cream as shown in Figure 4.5.3. The percentage alkali content increased from

0.86% in F5 to 1.08% in F5d. The formulated soaps F5, F5a, F5b and F5c had alkali content of 0.86%, 0.89%, 0.91% and 0.96% which are in a close range with the standard bath soap (Imperial leather). F5d had an alkali content of 1.08 which was slightly above the standard soap. Residual alkali in soap is attributed to higher saponification value of camel milk cream. Higher saponification value indicates need for addition of super fat or inclusion of unsaturated fatty acids.

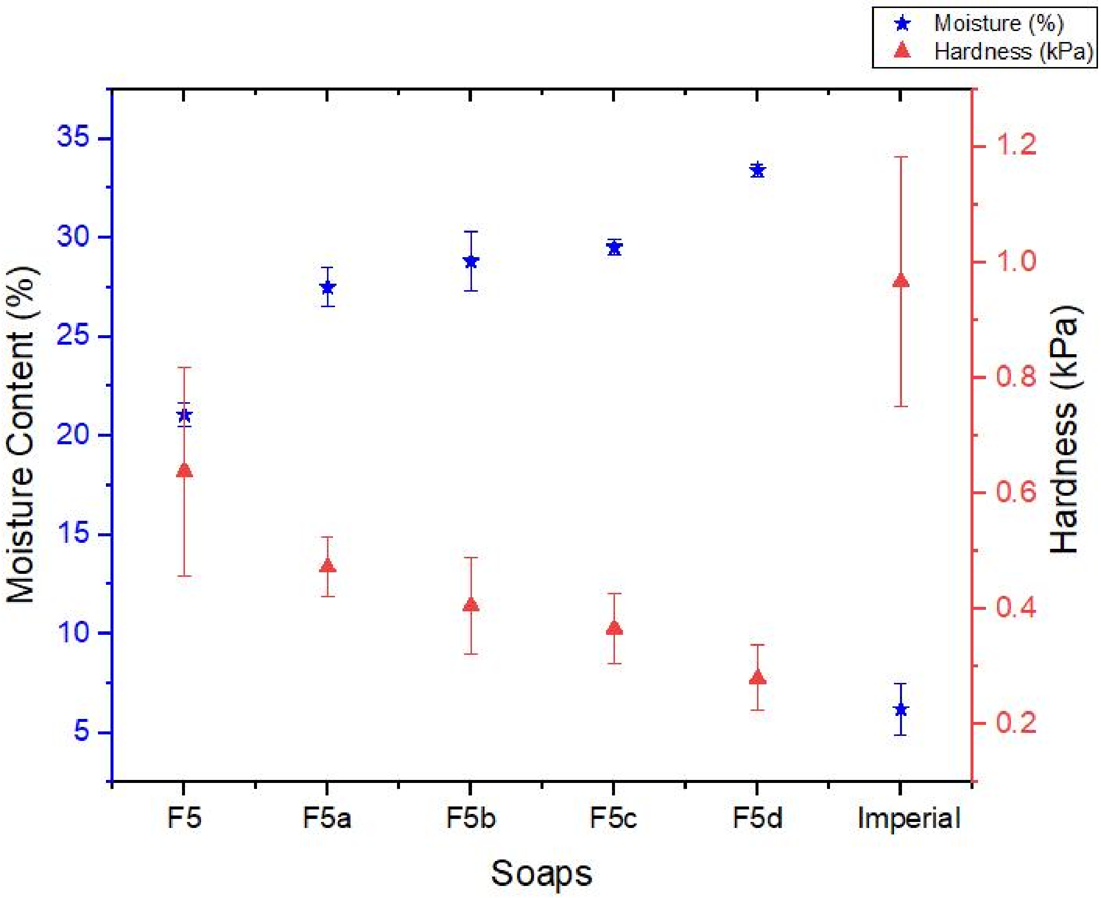
4.11.7 Effect of camel milk cream on moisture and hardness

Moisture content is a key parameter in determining a shelf-life of a soap. High moisture content in soap can cause hydrolysis reaction upon storage in which surplus water molecule can react with un-saponified fat to form a free fatty acid and glycerol (Alum & Nnchi, 2024). From the analysis it was noted that the moisture content increase with an increase in camel milk cream and the moisture content values of all soap samples (F5, F5a, F5b, F5c and F5d) were above the standard soap Imperial (fig. 4.4). The soap , F5a and F5b are below the moisture content values (29.05 %) obtained by Ogunsuvi and Akinnawo (2012). The moisture content values are all above (6-11%) the values obtained by Kuntom *et al.* (1996), and also above (22-26%) limit set by the Kenya Bereau of Standards (Kenya Bureau of Standards, 2021)

The results in Figure 4.4 shows that hardness decreases with an increase in camel milk cream. F5 recorded high value of 0.64 ± 0.18 KPa. The hardness values for all the soap samples (F5, F5a, F5b, F5c and F5d) were lower than that of the standard reference soap, Imperial Leather (0.97 kPa). Soap hardness is a physical parameter that rely on the nature of fatty acids use in soap making process. Saturated fatty acids produce hard soap while unsaturated fatty acids produce soft soaps (Alum and Nnchi, 2024). Camel milk cream contained approximately 59.33% saturated fatty acids and 40.75% unsaturated fatty acids (Karaman *et al*., 2022). However, the fatty acid composition of camel milk cream can vary depending on factors such as breed, diet, and lactation stage (Alhaj *et al.*, 2022).

Figure 4.4:

Effect of camel milk cream on moisture and hardness



Source: *Researcher (2024)*

Figure 4.4 illustrates the relationship between moisture content (%) and hardness (KPa) across different soap formulations (F5 to F5d) and a commercial reference soap (Imperial). The results show a clear trend: as the amount of camel milk cream in the soap increases, moisture content also increases, while hardness decreases. The formulated soap F5d recorded the highest percentage of moisture content (33.4±0.3%) and the lowest hardness ($0.281 \pm 0.056\ KPa$) . This may be attributed to presence of unsaponifiable and hydrophilic matter like lactose and proteins in camel milk cream which have water holding capacity in aqueous state (Kneifel *et al*., 1991).

Conversely, F5 (control soap), which contained no camel milk cream and the highest level of coconut oil, had a low percentage moisture content ($21.6 \pm 0.6\%$) and high hardness of (0.639 ± 0.181 KPa). This is attributed to the saturated fats -rich (55.45%) coconut oil, which is reported to produce hard soaps with low moisture (Selladurai & Kathiresapillai, 2019). The observed results for moisture content for all the formulated ranged between 21.6 to 33.4% which were significantly higher ($p<0.05$) than the moisture content ($6.2 \pm 1.3\%$) obtained for the standard soap and were also above the KEBS limit for bath soap's moisture content (Ogunsuyi & Akinnawo, 2012; 2014), reported a moisture content of 29.05% for a soap formulated using coconut oil and palm brunch. Moisture content determines soap's quality during shelf-life. Soaps with high moisture content are susceptible to hydrolysis during storage, where excess water reacts with remaining un-saponified fats to produce free fatty acids and glycerol (Mehasar *et al*., 2019). Formulations F5a and F5b achieved an optimal balance of moisture content and hardness.

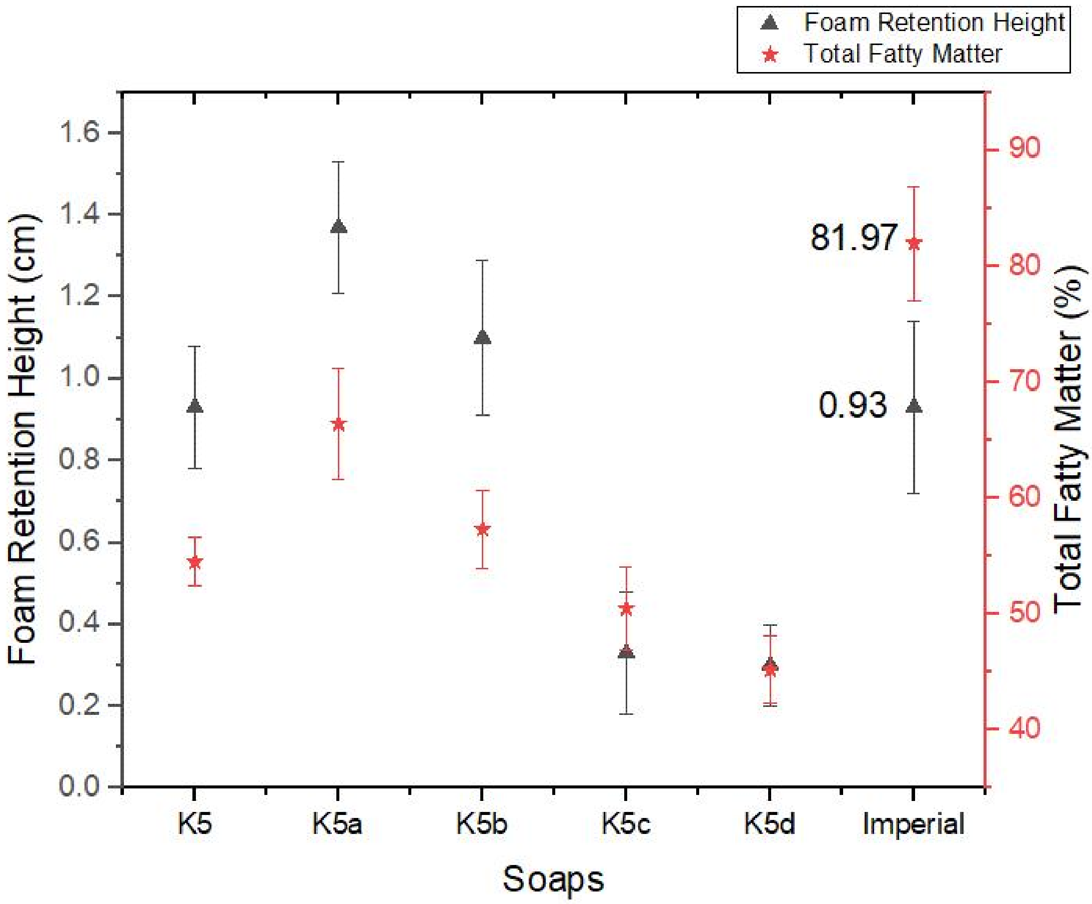
4.11.8 Effect of Camel milk Cream on Foam Stability and Fatty Matter

Figure 4.5 presents foam retention height and Total Fatty Matter (TFM) for the formulated soaps (F5–F5d) with rising camel milk cream and reduced coconut oil.

Formulated soap F5a recorded greater foam stability and highest percentage of total fatty matter. This may be attributed to moderate inclusion of camel milk cream. In contrast, formulated soaps F5b – F5d with increasing camel milk cream and decreasing coconut oil, showed a steady decrease in foam retention and total fatty matter. The increased foam stability and decreased total fatty matter may be attributed to decline in amount of coconut oil and increase in camel milk cream. Awang *et al*. (2001) associated low total fatty matter in a fresh soap with the presence of free alkali. According to KEBS and ISO 685 total fatty matter specifications, bath soap should have a total fatty matter of above 76% (Kenya Bureau of Standards, 2021). Among the formulated soaps analyzed F5a and F5b recorded total fatty matter of (66.43%) and (57.34%) respectively (fig 4.5). This could suggest their suitability for bathing as the values obtained were not far from the recommended limit.

Figure 4.5:

Effect of cream milk cream on foam stability and fatty mater



Source: *Researcher (2024)*

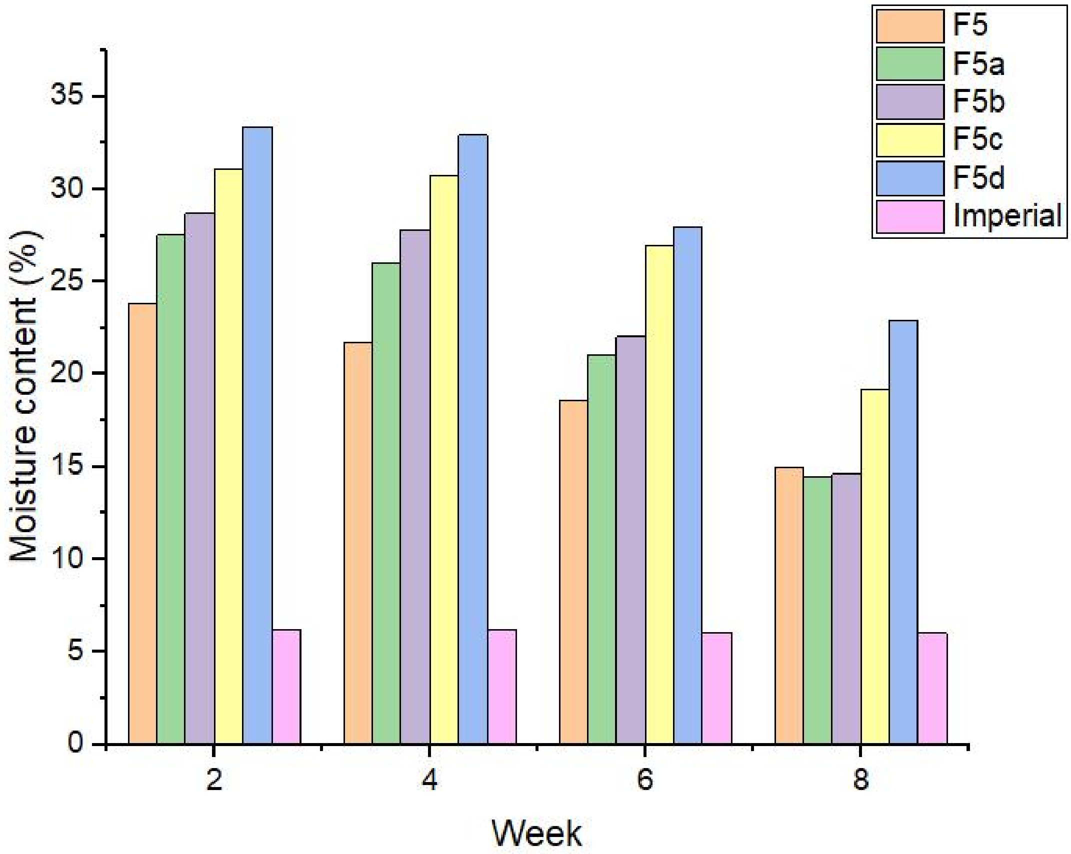
Foam stability increased initially with camel milk cream due to micelle formation and interfacial stabilization by medium-chain fatty acids and proteins, but at higher concentrations excess lipids acted as antifoaming agents, disrupting interfacial films and reducing foam retention. Foam stability is attributed to the presence of medium-chain saturated fatty acids, notably lauric (C12:0) and myristic (C14:0) acids, in camel milk cream, which enhance micelle formation and stabilize the foam structure (Aamir, 2019). According to Alum and Nnchi (2024), saturated and unsaturated fatty acids present in the oil blend used in soap formulation determines the soaps foam stability. Murti *et al*. (2024), reported that saturated fatty acids; lauric acid $CH_3(CH_2)_{10}COOH$ and myristic acid $CH_3(CH_2)_{12}COOH$ are foam boasters and stearic acid $CH_3(CH_2)_7CH{=}CH(CH_2)_7$ as foam stabilizer in soap. Oleic acid and linoleic acid are associated to soft stable foams (Iriany et al., 2020).

4.11.9 Effect of Camel Milk Cream on Shelf Life

Shelf-life of a product refers to the length of time over which a cosmetic product can retain its physicochemical, microbiological and sensorial properties from production date to the recommended period of use (Guaratini *et al*., 2006). Shelf-life studies are essential as it aid in in checking whether the essential properties are stable and within an acceptable range. The change in percentage of moisture content of the formulated soaps is presented in Figure 4.6. During 8 weeks for shelf-life studies, it was observed that in all the formulated soaps, the moisture content decrease from week 2 to week 8, an indication of natural dehydration during storage. This was expected as soap normally lose moisture upon storage (Nova *et al*., 2025). The standard soap (Imperial) maintained a consistent moisture content of 6% throughout the 8-week shelf-life. This stability is attributed to the presence of glycerin, a humectant that helps retain moisture, thereby ensuring hardness, stability, and an extended shelf life (Sukmawati *et al*., 2019). The findings are in line with the literature on effect of super fat on soap physicochemical parameters by Benjamin and Abbass. (2019), which revealed that soap storage causes evaporation of moisture resulting to increased hardness.

Figure 4.6:

Relationship between soaps moisture content and storage time



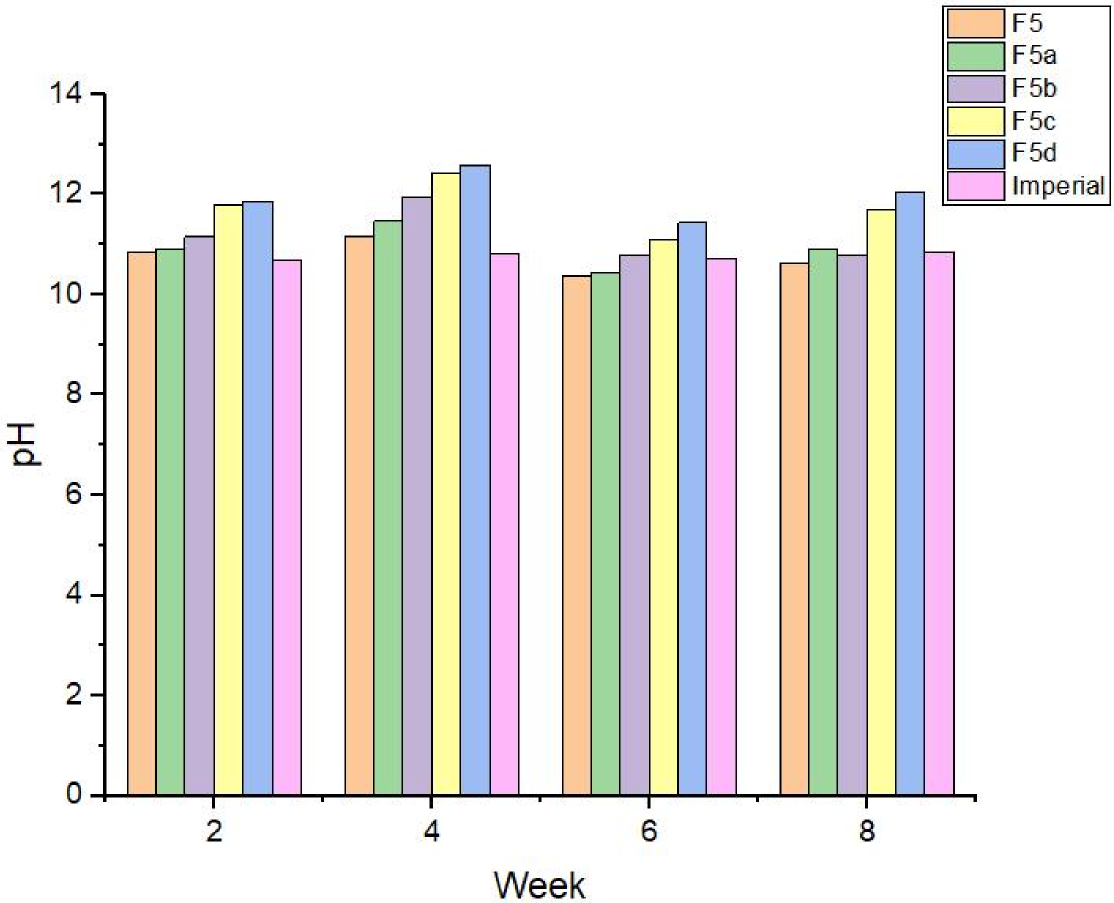
Source: *Researcher (2025)*

The pH values change with time during the shelf life can be characterized as semi-cured soap systems when related to bath soap containing cream from camel milk (Figure 4.7). In the early weeks of storage (Week 2), the pH of all samples (F5–F5d) was found to be alkaline, with values ranging approximately from 10.5 to 11.5. The alkalinity is attributed to residual sodium hydroxide that had not hydrolyzed the ester bonds in triglyceride fatty acids during the initial saponification process (Sytnik *et al*., 2021).

During week 4, most of the formulations recorded a noticeable increase in pH, especially those with a higher concentration of camel milk cream. During curing and with incomplete saponification reactions, segregation of residual alkali from the soap matrix may contribute to pH increase (Imani *et al*., 2025). The presence of milk components, such as proteins and fats, would also influence these processes by acting to buffer alkali reactivity and thereby alter neutralization rates (Vaia *et al*., 2006). The expiry date could not be established within the timeframe of the study.

Figure 4.7:

Relationship between soaps pH content and storage time



Source: *Researcher (2025)*

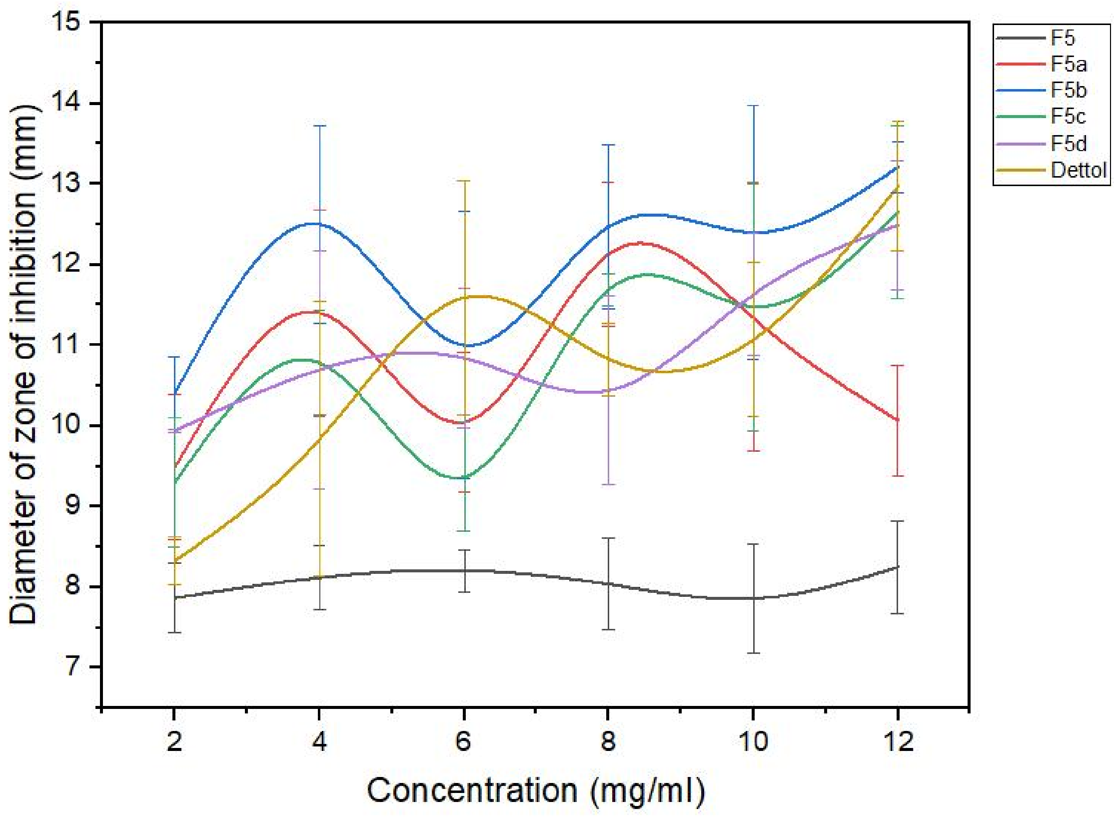
4.12 Effect of Camel Milk Cream on Antimicrobial Activity

4.12.1 Comparison of inhibition of the *S. aureus* at different soap formulations

The results in figure 4.8 showed that the negative control soap (F5) showed antibacterial activity against the S. *aureus*, with inhibition zones which ranged from 7.15 mm at 10 mg/mL to 9.49 mm at 4 mg/mL. Though the control soap showed antibacterial activity, a higher significant difference ($P \leq 0.05$) in antibacterial activity were observed when compared to the soaps formulated with camel milk cream (F5a, F5b, F5c, and F5d). This shows that the incorporation of camel milk cream in the soap enhances the antibacterial activity.

Figure 4.8:

Mean diameter of the zone of inhibition (mm) of formulated soaps against S. aureus at different concentrations



Source: *Researcher (2025)*

Soaps containing camel milk cream demonstrated a significant increase in antibacterial activity with an increase in the percentage of camel milk cream across all concentrations. Among the formulated soaps, F5b recorded the highest mean diameter of zone of inhibition ranging from 10.41 mm at mg/mL to 13.21 mm at 12 mg/mL. F5c and F5d soaps showed enhanced antibacterial activity at higher concentrations which were not consistently significant ($P \leq 0.05$), suggesting that increasing camel milk cream does not enhance antibacterial proportionately.

At higher concentrations, there was no significant difference ($P \leq 0.05$) in antibacterial activity of Dettol soap compared to formulated camel milk cream soaps. The findings suggested that the use of camel milk in the soap formulation significantly increases antibacterial activity against *S. aureus.* These findings are in concurrence with the findings obtained by There *et al*.(2022), that showed that goat milk soap had antibacterial activity against both S*taphylococcus aureus* and *Escherichia coli*. In concurrence with the findings, many studies reported camel milk as a rich source of antibacterial proteins that can be utilized in cosmetics formulations (Badawy *et al*., 2025; Yaseen & Hanee, 2019). The negative control soap (F5) had antibacterial activity due to alkaline nature of soap. Alkaline substances are barrier to bacterial growth as they inhibit the metabolism activity of the bacteria (Razmi *et al*., 2023). The findings suggest that the formulated camel milk cream-based soaps show viable antibacterial activity comparable to commercial antibacterial soap Dettol, particularly at higher concentrations, supporting the suitability of camel milk cream in bath soap formulation.

4.12.2 Comparison of inhibition of the *E. coli* at different soap formulations

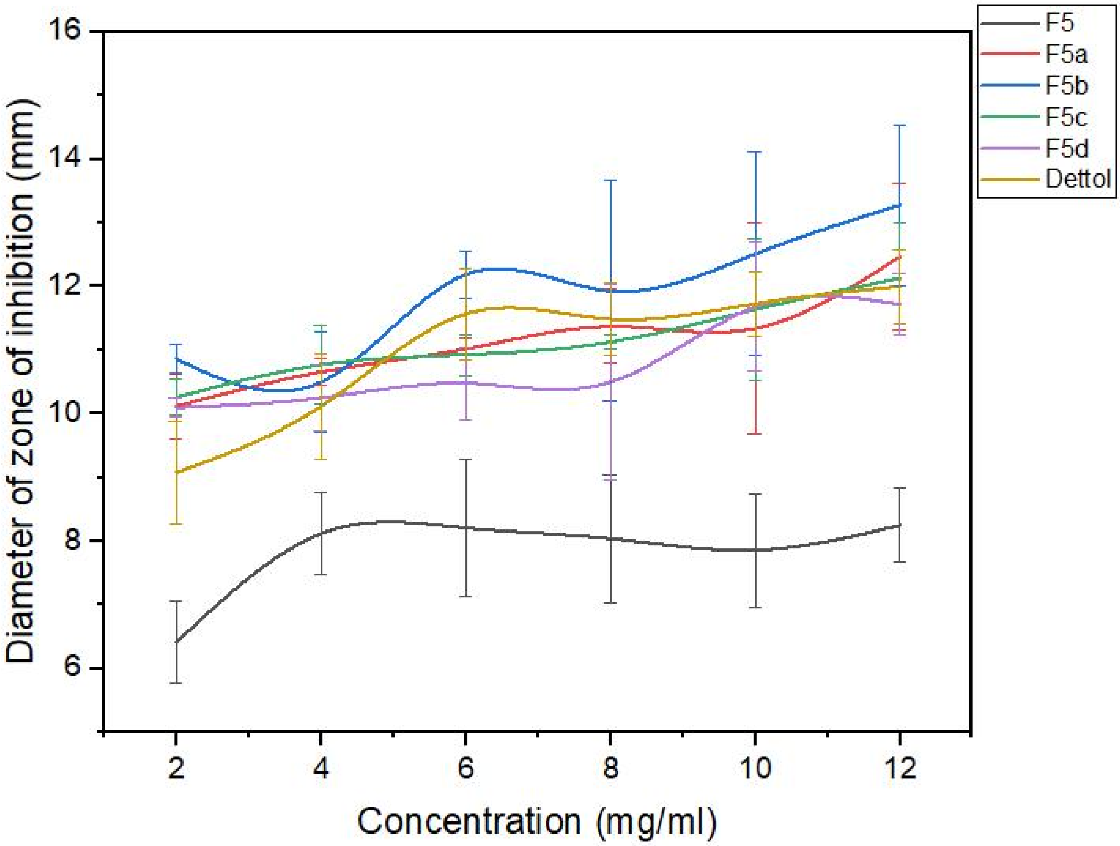
The findings presented in figure 4.9 showed a significant difference in antibacterial activity among soap formulations at equivalent concentrations. The negative control soap (F5) consistently demonstrated the lowest activity, with inhibition zones ranging from

8.17 to 9.44 mm, and no statistically significant increase ($P \leq 0.05$) at higher concentrations.

In contrast, the camel milk cream-based formulations (F5a – F5d) demonstrated significant increases ($P \leq 0.05$) in inhibition zones as concentration increased. Among them, F5b exhibited the highest zone of inhibition, increasing from 10.86 mm at 2 mg/mL to 13.28 mm at 12 mg/mL, suggesting strong antibacterial potential. However, the increase in antibacterial activity beyond 8 mg/mL was not significantly different ($P \leq 0.05$) when compared with other camel milk formulations (F5a, F5c, and F5d), nor was it significantly different from Dettol soap at comparable concentrations. In comparison, Dettol soap produced inhibition zones ranging from 9.08 mm to 12.00 mm. At a concentration of 12 mg/mL, the camel milk-based soaps F5b, F5a and F5c showed slightly larger inhibition zones than Dettol. Although the differences were not statistically significant ($P \leq 0.05$), the results indicate that camel milk-based soaps especially the soap formulation "F5b" shows strong antibacterial activity that is comparable to an existing commercial product. This suggests that the natural ingredients in F5b make it a promising alternative for creating effective antibacterial soaps.

Figure 4.9:

Mean diameter of the zone of inhibition (mm) of formulated soaps against E. coli at different concentrations



Source: *Researcher (2025)*.

4.13 Sensory Evaluation and Consumer Acceptability

Sensory evaluation refers to products' assessment of properties and consumer feeling using senses (touch, sight, smell) (Margeta *et al*., 2019). As the camel milk cream increased in the formulated soaps, the consumer rating of hardness increased, foamability and overall acceptability decreased while that of the skin irritation did not change (Figure 4.10.

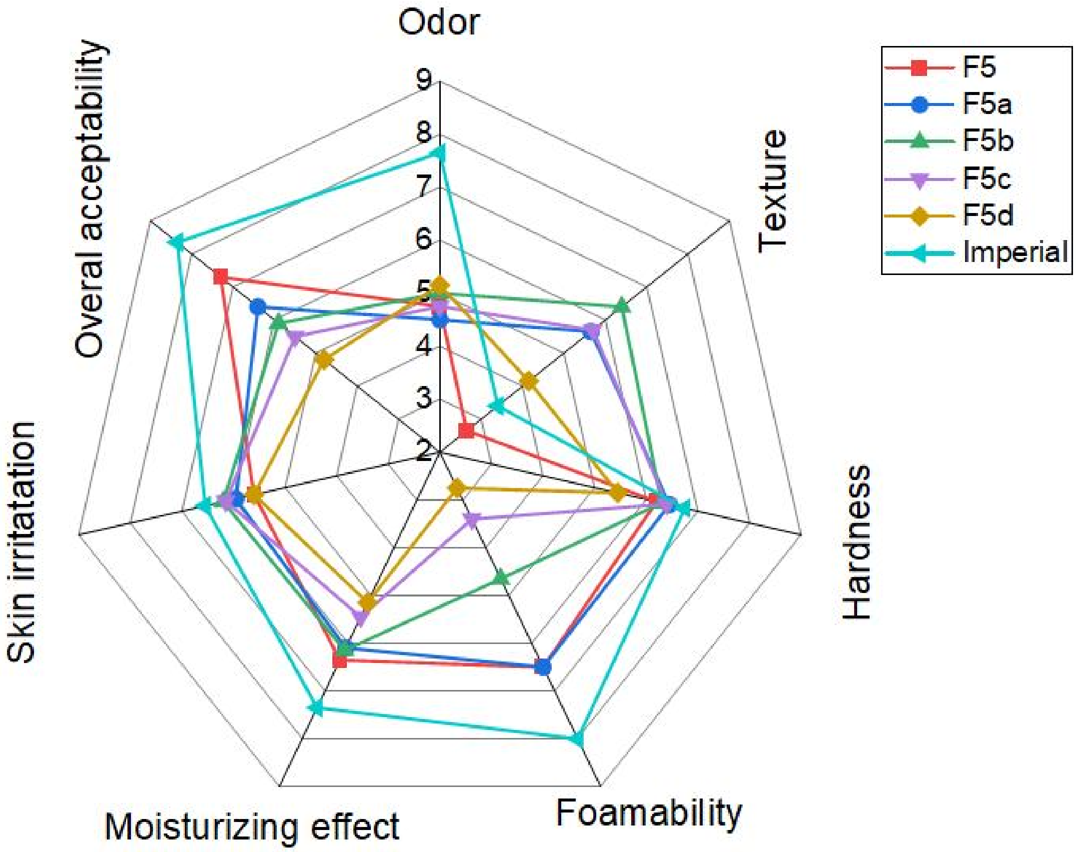
In terms of foamability, the F5 with 0% camel milk cream had a mean of 6.5 ± 1.9 with a verbal translation of extremely foamy that was comparable with the commercial standard soap (imperial). The foamability of the formulated soaps decreased with the increase in camel milk cream and decrease in coconut oil in the formulation. This is because of decrease in coconut oil which contains lauric acid $CH_3(CH_2)_{10}COOH$ which is a foam booster (Selladurai & Kathiresapillai, 2019).

The acceptability of the moisturizing effect seems to increase with an inclusion of camel milk cream in the formulation. F5b with 20% camel milk cream had a mean of 6.35 ± 1.69 with a verbal interpretation of moist. This is because camel milk cream alpha-hydroxy acids which hydrates the skin (Yaseen & Hanee, 2019). With regards to texture, the F5b (20% camel milk cream) had a highest mean of 6.3 ± 1.34 with a verbal translation of slightly rough. The skin irritation tests of the formulated soaps containing camel milk cream had no significant difference ($p<0.05$) from the standard soap (imperial soap). This is attributed to their pH values the were found to be within the KEBS accepted range.

With regards to overall consumers acceptability, the control soap (Imperial leather) was the most preferred with the rating of 8.4 (like very much), followed by F5, soap containing 0% camel milk cream with a rating of 7.3 (like moderately) followed by F5a soap containing 10%, F5b containing 20%, F5c containing 30% and F5d containing 40% camel milk cream had a rating of 6.75 like moderately), 5.95 (like slightly), 5.55 (like slightly), 4.9 (neither like or dislike) respectively. The low overall consumer acceptability of soaps formulated with camel milk cream is likely attributable to sensory attributes, particularly the inherent odor of camel milk cream, which 65% of panelists found unpleasant.

Figure 4.10:

Hedonic Scale rating for the overall acceptability of the formulated camel milk cream-based soap



Source: *Researcher (2025)*

In addition, variations in color, texture, or lather characteristics associated with the inclusion of camel milk cream may have further influenced negative perceptions. These sensory attributes collectively reduce consumer appeal despite the potential functional benefits of the formulation (Hashim, 2002).

4.14 Conclusion

The objectives were successfully attained in this study. Firstly, soap was formulated using camel milk cream and palm and coconut oils, exhibiting some potential for use in natural cosmetics applied in skincare. The second outcome was based on physicochemical analyses: the soap complied with acceptable standards and had a pH range of 10.17–11.51; total fatty matter (TFM) was within the acceptable range, reaching up to 66.43%; and the moisture content was also within the expected range of 21.06–33.4%. It was observed that both foam stability and hardness were similar to the commercial bath soap Imperial.

The third test was the antibacterial activity, where the inhibition zone diameter was larger (up to 21.3 mm for *Staphylococcus aureus* and 19.7 mm for *Escherichia coli*, $p < 0.05$), establishing the higher antimicrobial ability of the soap. Notably, these results were comparable to Dettol soap, a widely used commercial antibacterial soap, indicating the effectiveness of camel milk cream as a functional ingredient. Sensory evaluation by 20 panellists displayed consumer acceptability, as well as positive comments concerning moisturizing effect, skin smoothness, and general user satisfaction; thereby, the results indicate that camel milk cream-based soap is a possible candidate for skincare cosmetics including bar soap formulations.

This study accomplished the demonstration of the feasibility of producing high-quality bath soap with camel milk cream used as a key ingredient. The optimized 20% camel milk cream and 20% coconut oil formulation had acceptable physicochemical properties, including a pH of 10.82, TFM of 66.43%, and moisture content of 25.8%, all within the acceptable ranges for bath soap. The antibacterial studies gave promising results, with the inhibition zone reaching 13.28 mm for *E. coli* and 13.21 mm for *S. aureus*. In addition, the sensory evaluation showed good acceptance on the consumer level, especially with formulations having camel milk cream between 10% and 20%, which brings about skin smoothness and moisturizing effects. The findings, therefore, validate the potential of camel milk cream as an advantageous natural ingredient to produce highly effective and consumer-friendly skincare products.

This study had certain limitations in spite of the positive results. Only two bacterial strains were used to evaluate the antibacterial activity *in vitro*, which may not accurately reflect the wide range of skin pathogens that are encountered in real-world situations. Future research should broaden the scope of microbial testing to encompass resistant strains, fungi, and a greater variety of skin-relevant microorganisms. Additionally, no *in vivo* testing was done to evaluate long-term effects. Clinical dermatological trials on human subjects should be a part of future research to assess skin benefits. To support commercial production, studies of shelf-life and stability over an extended period of time under varied storage conditions are also required.

CHAPTER FIVE: GENERAL DISCUSSION OF THE STUDY

The results of this thesis are divided into two different but related sections. The first section reviews the literature on potential application of camel milk as a therapeutic ingredient for soap. The second section of the thesis is comparative review of milk-enriched and plant-based soaps formulation, composition and skin benefits. The third section is a study on the formulation and evaluation of physicochemical properties of bath soap containing camel milk cream. The research gap from the first section of the thesis which is the underutilization of camel milk cream as an ingredient in soap formulations despite being a rich source of polyunsaturated fatty acids and bioactive proteins, which offer promising benefits for skin nourishment and protection against bacterial infections.

The mentioned research gap in first section, formed the foundation for research objectives of the second part of the thesis. These objectives were; To formulate bath soap containing camel milk cream as potential cosmetic soap for skin care use. To analyse the physicochemical properties of the bath soap containing camel milk cream. To conduct antibacterial activity for the formulated camel milk cream-based bath soap. The last objective was to conduct sensory evaluation tests of the formulated camel milk cream-based bath soap.

The key component of this study was comparison with commercial bathing and antibacterial soaps such as Dettol and Imperial lather. Formulated soaps with 10–20% camel milk cream showed comparable antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*. Also, the physicochemical properties such as pH, total fatty matter, foam stability, and hardness were also consistent with those of Dettol and Imperial Leather, supporting camel milk cream’s potential as a natural alternative in antibacterial skincare soaps.

Kenya is the leading producer of camel milk in the world as it records approximately 1.165 million metric tonnes of camel milk by volume every year (Oselu *et al*., 2022) However, despite Kenya being on the global map as a leading producer of camel milk, the availability of camel milk derived cosmetics products remains limited in the market due to unawareness of its cosmetic use and market value.

The sensory evaluation was conducted by 20 panellists to evaluate the consumer preference for the formulated camel milk cream soaps. The control soap (Imperial) was the most preferred with the rating of 8.4 (like very much), followed by F5, soap containing 0% camel milk cream with a rating of 7.3 (like moderately) followed by F5a soap containing 10%, F5b containing 20%, F5c containing 30% and F5d containing 40% camel milk cream had a rating of 6.75 like moderately), 5.95 (like slightly), 5.55 (like slightly), 4.9 (neither like or dislike) respectively. Despite the high preference for the control soap, as shown in this study, camel soap containing 10% camel milk cream was the most preferred among those formulated with the camel milk cream. Therefore, if the panellists were to be presented with only the samples containing the camel milk cream, then the 10% formulation would be the most preferred. According to this study, it is possible to formulate acceptable cream base-bath soap using low concentration of camel milk cream in the formulations. Forty-five percent of the panellists reported that the soaps formulated with camel milk cream exhibited an unpleasant odor, which may be attributed to the inherent characteristic smell of camel milk cream (Hashim, 2002). This sensory limitation could be mitigated through the incorporation of suitable fragrances as additives during formulation.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The study evaluated the physicochemical properties, antibacterial activity and sensory attributes of the bath soap incorporated with camel milk cream to assess the possible application of camel milk cream as potential ingredient for soap formulation.

The first objective was to test the physicochemical properties of the soaps formulated with camel's milk cream. It was deduced that The Soap with 12.5% Camel Cream (F5b) showed the best formulations. It exhibited optimal balance of pH, alkali content, moisture content, hardness, foam stability and total fatty matter making it suitable for skincare use. The soaps possessed somewhat accepted physicochemical values with pH ranging from 10.17 to 11.51, which are generally accepted pH values for bath soaps. The Total Fatty Matter (TFM) content recorded ranged between 45.19 and 66.43%, suggesting a high ability to cleanse and condition the skin. The moisture content values fell between 21.06 and 33.4%, which protects product stability and shelf-life. Foam stability was noted between 0.33 cm and 1.37 cm, and hardness ranged from 0.281 to 0.639 kPa; all these supports its compatibility with user performance. These physicochemical properties were compared with Imperial Leather commercial soap and exhibited comparable performance, confirming the use of camel milk cream as an ingredient for bath soap formulation.

The second objective was to conduct antibacterial activity for the formulated soaps containing camel milk cream. F5b had strong antibacterial activity, indicating its potential as a natural antimicrobial in skincare products.

The results showed that soap with 0% camel milk cream (negative control) had antibacterial activity. However, incorporation of camel milk cream in the soap formulation significantly increases the antibacterial activity as there was an increase in the diameter (mm) of zone of inhibition against both *Staphylococcus aureus* and *Escherichia coli*. Also, an increase in soap concentration has no significant difference in antibacterial activity. This makes formulated soaps containing low concentration of camel milk cream ideal soaps for bathing. Formulated soaps especially those containing 10 – 20% camel milk cream showed inhibition zones almost equal or slightly more than those of Dettol. This suggests that soaps formulated from camel milk cream are comparable to commercial soaps like Dettol in relation to antibacterial efficacy.

The third objective was to conduct sensory evaluation tests of the formulated bath soap containing camel milk cream. F5b achieved the best balance of sensory attributes including odor, texture skin mildness and formability moisturizing, making it suitable for skincare applications.

6.2 Study Limitations

Even though the study had a promising result, there were some limitations. First, the antibacterial activity was tested against only two bacterial strains (*Staphylococcus aureus* and *Escherichia coli*), which may not comprehensively represent the full spectrum of skin-related pathogens. Second, the study relied on *in vitro* antibacterial assays, which do not fully replicate real-life skin conditions or interactions with sebum, sweat, and the skin microbiome. Third, the sensory evaluation involved a limited number of untrained panellists, which may introduce subjective bias and limit the generalizability of the results. Additionally, long-term stability and shelf-life testing of the formulated soaps were not performed, which is crucial for commercial product development.

6.3 Recommendations and Future Research

The incorporation of camel milk cream in bath soap formulation showed promising results that the camel milk cream can be a potential ingredient for skincare cosmetics products.

This study recommends that future research should focus on the incorporation of camel milk cream into a broader range of cosmetic products, with emphasis on evaluating their physicochemical properties and consumer acceptability to assess their potential for commercial application. Furthermore, in vivo trials involving human subjects should be undertaken to provide more conclusive evidence regarding the safety, efficacy and dermatological benefits of the formulations. It was also recommended that the long-term physicochemical stability of the soap formulations be evaluated under different storage conditions to determine their shelf life and establish an accurate expiry date. Such investigations would contribute to the advancement of knowledge in cosmetic formulation and support the development of safe and stable natural cosmetics.

6.4 Publication

Oginga, E., Toeri, J., Marete, E., & Arimi, J. (2024). Potential application of camel milk as a therapeutic ingredient in bath soaps and shampoos. *Dermatology Research and Practice*, *2024*(1), 4846339. https://doi.org/10.1155/2024/4846339

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APPENDICES

Appendix A: Publication

Review Article

Potential Application of Camel Milk as a Therapeutic Ingredient in Bath Soaps and Shampoos

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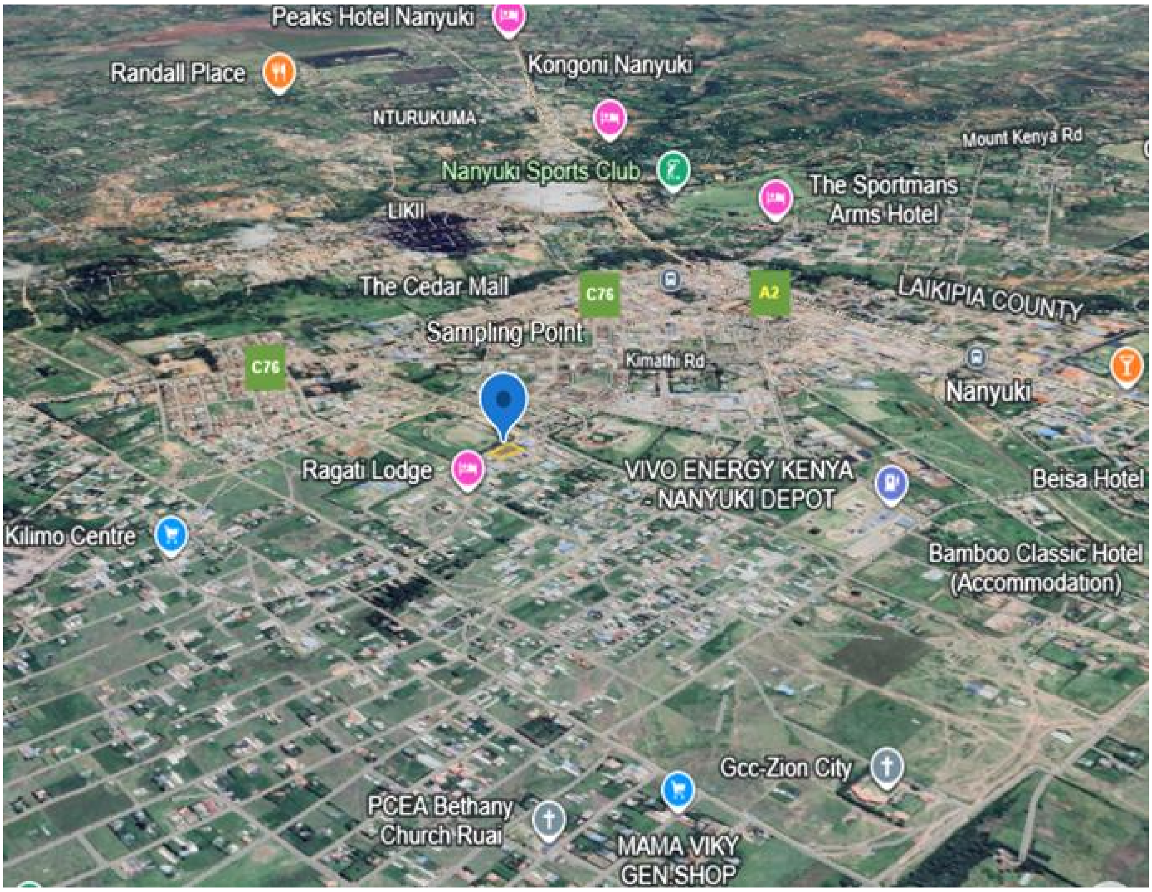
The increasing worldwide market for natural-ingredient-based cosmetic toiletries is fuelled by the awareness of the dangers of synthetic cosmetics and benefits of natural-based cosmetics on the skincare and management of skin disorders. Besides naturally formulated cosmetics being biodegradable, they also contain ingredients which are chemically beneficial to human skin. Milk-based cosmetics are very promising since milk is rich in essential components such as lactoferrins, vitamins, and lactic acids, which have shown therapeutic properties against disorders such as skin cancer, acne scars, and dandruff. One of the milk that is very promising in the cosmetics industry is the camel milk. Currently, there is limited information in literature regarding the use of camel milk in cosmetics and their benefits. Camel milk stands out from bovine milk following its unique therapeutic properties and chemical composition, making it a potential ingredient for skincare and haircare products such as bath soaps and shampoos. The aim of this paper is to review the available literature on camel milk composition and evaluate the contribution of camel milk constituents to cosmetics.

Appendix B: Sample Site for Fresh Camel Milk



Appendix C: Plagiarism Report

DrillBit

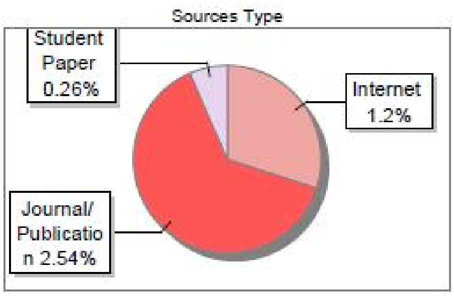
The Report is Generated by DrillBit Plagiarism Detection Software

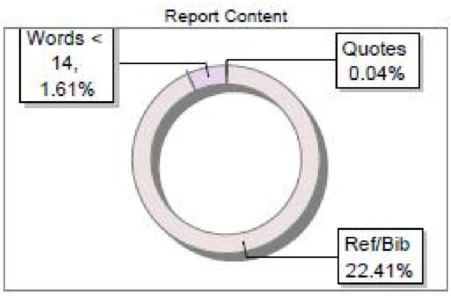
Submission Information

Author Name	ELLY OGINGA
Title	FORMULATION AND EVALUATION OF PHYSICOCHEMICAL PROPERTIES OF BATH SOAP CONTAINING CAMEL MILK CREAM
Paper/Submission ID	4205465
Submitted by	jwmaina@must.ac.ke
Submission Date	2025-08-04 15:20:14
Total Pages, Total Words	126, 27251
Document type	Thesis

Result Information

Similarity **4 %**





Exclude Information

Database Selection

Appendix D: Sensory Evaluation Questionnaire

SENSORY EVALUATION OF CAMEL MILK CREAM SOAP

Study title: Formulation and Evaluation of Physicochemical Properties of bath Soap Containing Camel Milk Cream

PART A: CONSENT

Dear Panellist,
You are invited to participate in a research study aimed at assessing the sensory acceptability of bath soap formulated with camel milk cream. Your participation will involve assessing selected samples of the formulated soaps based on sensory attributes such as texture, foamability, odour, hardness, skin irritation and moisturizing effect and overall acceptability.

The information collected will be used strictly for academic and research purposes and will contribute to the development of improved personal care products. Your responses will remain confidential and anonymous.

Please note the following:

1) Participation in this study is entirely voluntary.
2) You have the right to withdraw at any time without any consequences.
3) There are no known risks associated with participation.
4) No personal identifiers will be linked to your responses.

PART B: SENSORY EVALUATION USING HEDONIC SCALE

Participants details

1. Please indicate your gender
a) Male ☐ b) Female ☐
2. Indicate your Age bracket
a)18- 22 years ☐ b) 23-27 years ☐ c) 28-32years ☐ d) 33-37 years ☐
e) above 37 ☐

1. **Odor/Smell**

Unwrap the soap and bring it to your nose a distance of about 2 cm. Sniff the soap and evaluate the odor/smell as per the scale provided.

Rating Scale	Soap Samples					
	ABCD	ABDC	ACBD	ACDB	ADBC	ADCB
Extremely strong-9						
Very strong -8						
Strong-7						
Slightly strong-6						
Neither strong nor weak-5						
Slightly weak-4						
Weak-3						
Very weak-2						
Extremely weak-1						

2. **Texture**

You are required to clean and dry your hands before handling the soap.

Hold the soap in your hand and use your fingertips to touch the surface and evaluate the texture as per the scale.

Rating Scale	Soap Samples					
	ABCD	ABDC	ACBD	ACDB	ADBC	ADCB
Extremely rough-9						
Very rough -8						
Rough-7						
Slightly rough-6						
Neither rough nor smooth-5						
Slightly smooth-4						
Smooth-3						
Very smooth-2						
Extremely smooth-1						

3. **Hardness**

Gently press the soap in your palm, rate the hardness as per the scale.

Rating Scale	Soap Samples					
	ABCD	**ABDC**	**ACBD**	**ACDB**	**ADBC**	**ADCB**
Extremely hard-9						
Very hard -8						
Hard-7						
Slightly hard-6						
Neither hard nor soft-5						
Slightly soft-4						
Soft-3						
Very soft-2						
Extremely soft-1						

4. **Foamability**

You are provided with 5.0 g of a soap sample and 500 ml of clean water in a basin. Wet your hands and the entire soap sample with the water. Rub the soap between your palms under the running water until it is fully consumed. Thoroughly stir the water in the basin using your hand with back–forth motion (1 back–forth lap =½ sec) for one minute. Evaluate the foamability of the soap sample by observing the amount of lather produced during application.

Rating Scale	Soap Samples					
	ABCD	**ABDC**	**ACBD**	**ACDB**	**ADBC**	**ADCB**
Extremely foamy-9						
Very foamy -8						
Highly foamy-7						
Moderate foamy-6						
Neither low nor highly faomy-5						

Moderate foamy-4						
Low foamy-3						
Very low in foamy-2						
No faom-1						

5. **Moisturizing effect**

You are provided with 5.0 g of a soap sample and clean water. Wash the forearm evaluation site with a clean water. Wet your hand and soap. Rub the soap between your hands and apply on the evaluation site, wait for about 3 minutes, then evaluate how your skin feels in terms of hydration.

Rating Scale	**Soap Samples**					
	ABCD	**ABDC**	**ACBD**	**ACDB**	**ADBC**	**ADCB**
Extremely moist-9						
Very moist -8						
Moist-7						
Slightly moist-6						
Neither moist nor dry-5						
Slightly dry-4						
Dry-3						
Very dry-2						
Extremely dry-1						

6. **Skin irritation**

After applying soap on your arm, evaluate how your arms feel in terms of itchiness or soothing.

Rating Scale	**Soap Samples**					
	ABCD	**ABDC**	**ACBD**	**ACDB**	**ADBC**	**ADCB**
Extremely soothing-9						
Very soothing -8						
Soothing-7						
Slightly soothing-6						

Neither soothing nor itchy-5						
Slightly itchy-4						
Itchy-3						
Very itchy-2						
Extremely itchy-1						

7. **Overall acceptability**

Rating Scale	**Soap Samples**					
	ABCD	**ABDC**	**ACBD**	**ACDB**	**ADBC**	**ADCB**
Like extremely-9						
Like very much -8						
Like moderately-7						
Like slightly -6						
Neither like nor dislike-5						
Dislike slightly-4						
Dislike moderately-3						
Dislike very much-2						
Dislike extremely-1						

Sample Code……………. Comment……………………………………..……
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