Pharmacognostic Study of Hibiscus Flower and Pomelo Fruit With Applications In Cosmetics

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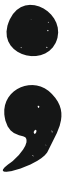

DeepScience

Published, marketed, and distributed by:

Deep Science Publishing
USA | UK | India | Turkey
Reg. No. MH-33-0523625
www.deepscienceresearch.com
editor@deepscienceresearch.com
WhatsApp: +91 7977171947

ISBN: 978-93-49307-91-9

E-ISBN: 978-93-49307-03-2

https://doi.org/10.70593/978-93-49307-03-2

Citation: Roy, S., Pal, B., Garai, S., & Rakshit, S. (2025). *Pharmacognostic Study of Hibiscus Flower and Pomelo Fruit With Applications In Cosmetics*. Deep Science Publishing. https://doi.org/10.70593/978-93-49307-03-2

Preface

This book explores the pharmacognosy, the scientific study of drugs from natural sources. The term combines the Greek words for "drug" and "knowledge," reflecting its rich historical and scientific heritage. Pharmacognosy connects traditional knowledge and modern science, covering the chemistry, botany, and therapeutic applications of natural substances. The field's relevance extends beyond academia, embodying the relationship between nature and health. This book delves into the medicinal, toxic, and nutritional aspects of natural products like Hibiscus sabdariffa and the Pomelo fruit, alongside innovative extraction methods that enhance their purity and efficacy. Readers will gain insights into both the historical uses and cutting-edge scientific research of plant-based medicines, understanding their potential in treating diseases and advancing future discoveries. This book provides a comprehensive look at the past, present, and future of pharmacognosy, bridging ancient wisdom with modern scientific developments.

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Deep Science Publishing
https://doi.org/10.70593/978-93-49307-03-2

Chapter 1

Introduction

1 Introduction

The term "pharmacognosy" was first introduced between 1811 and 1815. Originally, it referred to "materia medica," encompassing the knowledge of medicinal substances or pharmacology. The word is derived from two Greek terms: pharmakon (meaning "a drug") and gignosko (meaning "to acquire knowledge of") (Evans, 1996) **[Kinghorn, A. D. (2001)]**. Pharmacognosy is the study of medicine derived from natural sources that include plants, animals, and microorganisms, and the scope of the field depends on knowledge about the safety, purity, and efficacy of complex multi compound products **[Leisegang, K. (2021)]**.

The field of pharmacognosy is vast, focusing on the scientific exploration of natural substances, including crude drugs and medicinal products like enzymes, vitamins, antibiotics, pesticides, allergens, and allergenic extracts. It also involves the study of excipients such as colouring and flavouring agents, emulsifiers, suspending agents, diluents, fillers, disintegrants, anaesthetic aids, sweeteners, binders, adhesives, and solidifiers. Moreover, it encompasses research in areas like phytochemistry, microbial chemistry, biosynthesis, biotransformation, chemotaxonomy, and other aspects of biological and chemical sciences. This discipline also examines plants that are toxic, hallucinogenic, or teratogenic, as well as natural sources for oral contraceptives, aphrodisiacs, spices, beverages, and condiments. Its history stretches back to ancient times, as seen in evidence of Neanderthals using medicinal plants such as yarrow and marshmallow over 60,000 years ago.

Early humans discovered the therapeutic properties of plants through observation, trial and error, accidental findings, curiosity, and the search for food. Over time, they developed significant expertise in medicinal plants, leading to the emergence of individuals skilled in identifying, testing, and applying these natural remedies to treat

illnesses **[Alamgir, A. N. M., & Alamgir, A. N. M. (2017)]**. *Hibiscus sabdariffa*, commonly known as “red sorrel” or “roselle,” belongs to the Malvaceae family.

This medicinal plant has gained worldwide recognition and comprises over 300 species, primarily distributed across tropical and subtropical regions. Roselle thrives in a variety of soils under warm and humid climatic conditions. The plant is a rich source of organic acids, including citric, malic, tartaric, and allo-hydroxycitric acids. It is also valued for its high content of beta-carotene, vitamin C, proteins, and total sugars. Roselle contains numerous phytochemicals with medicinal significance, contributing to its reputation for both nutritional and therapeutic benefits. Various parts of the roselle plant—such as seeds, leaves, fruits, and roots—are used in food preparation and herbal medicine as potential non-pharmacological treatments. Extracts from roselle have been shown to play a significant role in addressing a range of medical conditions, including cardiovascular disorders, helminthic infections, and cancer. Additionally, roselle exhibits antioxidant properties and is used in the management of obesity. Native to India, Malaysia, Sudan, Egypt, Nigeria, Mexico, Saudi Arabia, Taiwan, the West Indies, and Central America, Hibiscus sabdariffa is a plant that is commonly cultivated in underdeveloped nations. Its stem, leaves, calyces, and seeds are used in medicine, industry, and other fields. Vitamins, minerals, protein, dietary fiber, carbs, and bioactive substances are all abundant in roselle calyces.

The primary components of roselle that have medicinal value are flavonoids, primarily anthocyanins, organic acids, and polysaccharides. A possible source of bioactive compounds with strong antioxidant-antiradical, anti-inflammatory, anti-obesity, antihyperlipidemic, antihypertensive, diuretic, antiurolithicatic, antimicrobial, anticancer, hepatoprotective, and renoprotective properties is the dried calyces. Hibiscus sabdariffa's safety and toxicological characteristics should be taken into account because it has been demonstrated to alter risk factors associated with metabolic syndrome. The dosage of the extract and its bioactivity is difficult to elucidate due to heterogeneity in studies. The biological potential of hexahydroxysulfonic acid has been assessed through various laboratory-based studies. Its antioxidant properties were analyzed using 2,2-diphenyl-1-picrylhydrazyl (DPPH•) and 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS+) radical scavenging, ferric reducing antioxidant power, nitric oxide radical scavenging, and Fenton reaction assays. These properties are attributed to phenolic acids, flavonoids, and anthocyanins, which help neutralize free radicals. The antihypertensive effects of hexahydroxysulfonic acid were examined using an angiotensin-converting enzyme inhibitory assay, where anthocyanins displayed competitive inhibition of angiotensin-converting enzyme activity. Additionally, the cardioprotective potential of hexahydroxysulfonic acid calyx aqueous extract was studied in doxorubicin-induced cytotoxicity in rat heart-derived H9c2 cells. Its antibacterial activity was evaluated using the disk diffusion method against various

Gram-positive and Gram-negative bacteria. The anticancer potential of hexahydroxysulfonic acid calyx extracts was investigated in a murine melanoma cell line, human umbilical vein endothelial cells, and the Michigan Cancer Foundation-7 human breast cancer cell line. The aqueous extract selectively targeted Michigan Cancer Foundation-7 cells, while the methanolic extract inhibited melanoma cell proliferation, migration, and tube formation in a dose-dependent manner. Studies conducted in living organisms have explored the neuroprotective effects of hexahydroxysulfonic acid calyxes in ischemic brain injury-induced Wistar rats and cypermethrin-induced oxidative stress in male house mice (Mus musculus). Its hepatoprotective properties were also assessed in Wistar rats treated with 2,4-dinitrophenylhydrazine. Furthermore, the anti-diabetic activity of hexahydroxysulfonic acid calyxes was evaluated in alloxan- and streptozotocin-induced diabetic rats, with its antioxidant effects linked to its anti-diabetic potential. Additionally, hexahydroxysulfonic acid calyxes have been reported to exhibit anti-obesity effects in rats subjected to high-fat, high-fructose diets [**Singh, P., Khan, M., & Hailemariam, H. (2017)]**. *Hibiscus sabdariffa* (L.) is a valuable source of anthocyanins, with their synthesis boosted by callus formation and elevated sucrose levels. Acidified ethanol was utilized to extract these pigments, and the dye was characterized using GC–MS analysis. The potential use of this natural dye in textile applications was explored, highlighting how fabric type can affect the dyeing process. The pigment's colour was observed to change based on pH and exhibited resilience to diverse environmental conditions **[Sankaralingam, B., Balan, L., Chandrasekaran, S., & Muthu Selvam, A. (2023)]**.

The calyces of *Hibiscus sabdariffa* are brightly red due to their high anthocyanin content. They are also rich in vitamins, minerals, and pectin. Traditionally, dried calyces were used to make beverages, while fresh calyces were transformed into products like jams and jellies. In traditional medicine, the calyces were utilized to treat a variety of conditions, ranging from constipation to heart-related disorders **[Sipahli, S. (2017)]**.

Pomelo (*Citrus grandis L.*), also referred to as Chinese grapefruit, shaddock, or chakotra (in Hindi), is a member of the Rutaceae family and is originally found in the tropical climates of Southeast Asia. The fruit is characterized by a rind that can range from yellowish to greenish and a flesh that can be white or pink, typically classified into these two types. Its taste is a blend of sweetness with mild acidity and a hint of bitterness. The fruit varies in size, with diameters ranging from 10 to 30 cm and weights between 1 and 2 kg, depending on the cultivar. Pomelo is often enjoyed as fresh fruit, juice, a salted dip, preserved snacks, or in salads. It is mostly water and is an excellent source of amino acids, essential minerals like potassium (K) and phosphorus (P), folic acid, and vitamins, including vitamin C, thiamine, riboflavin, and B12. The fruit also contains potent antioxidants such as β-carotene, polyphenols, terpenoids, alkaloids, β-sitosterol, and flavonoids (notably neohesperidin, naringenin, hesperidin, and naringin), along with

essential oils. Pomelo, along with other citrus fruits, has demonstrated powerful antioxidant activity and has been associated with various health benefits, including antimicrobial, anti-inflammatory, hypolipidemic, hypoglycemic, and anticancer properties. Additionally, it is used in the treatment of skin conditions, diabetes, scurvy, and urinary tract disorders **[Singh V, Kushwaha R, Kaur D, Kumar S. Mosambi]**.

Pomelo (*Citrus maxima* Merr.), recognized as a well-known fruit and a traditional folk medicine, is widely cultivated in China. The non-edible tissues of pomelo include peels, seeds, and segment membranes, which are generally discarded. The relationships between polysaccharides found in different pomelo tissues remain unclear. Four types of water-soluble polysaccharides—pomelo peel polysaccharides (PPPs), pomelo seed polysaccharides (PSPs), pomelo pulp polysaccharides (FPPs), and segment membrane polysaccharides (SMPs)—were extracted from the peels, seeds, pulps, and segment membranes of pomelo, respectively·. Green Chemistry promotes the utilization of food waste, chemical by-products, and industrial residues to support environmental sustainability. Among the most widely cultivated fruits globally are citrus fruits, including apples and bananas, generating approximately 48 million tons of waste. Researchers have explored the potential reuse of citrus peels with a focus on sustainability and environmental benefits. While most peels are discarded through landfilling, incineration, or composting, some are repurposed as animal feed. However, their use as humus presents challenges due to low nitrogen content and high acidity. Extracting valuable bioactive compounds such as D-limonene offers a more economically viable approach to waste utilization. Sicily is recognized as a key biodiversity hotspot in the Mediterranean, home to 3,252 species and 321 endemic taxa. Traditional Sicilian agroecosystems exhibit unique characteristics that support rare species and conservation efforts. Citrus cultivation is widespread in Sicily, with flavedo and seeds being the primary by-products of citrus processing. These wastes are rich in bioactive compounds such as terpenes, flavonoids, and limonoids. Essential oils derived from flavedo are valued for their aromatic properties and are widely used in the food and cosmetic industries. In food applications, citrus essential oils help preserve the food matrix by preventing rancidity and maintaining nutritional quality, color, and flavor. Pomelo (*Citrus maxima*) is one of the primary species within the *Citrus* genus, alongside *Citrus reticulata Blanco* and *Citrus medica L.*, as determined through biochemical polymorphism and karyotype analysis. Pomelo essential oils have diverse applications in fragrance, aromatherapy, spiritual practices, and cosmetics. This study examines the chemical composition of essential oils extracted from five different pomelo cultivars grown in Palermo, Sicily, both individually and in combination, to evaluate potential synergistic or antagonistic effects. The findings indicate that inhibiting α-amylase and α-glucosidase—enzymes responsible for carbohydrate digestion—can significantly reduce postprandial blood glucose spikes. This suggests that pomelo essential oils may

offer a promising strategy for managing blood sugar levels in individuals with type 2 diabetes or those at risk **[Wu Z, Li H, Luo Y, Chen G, Li J, Wang Y, Yang Y, Tan H.]** Tables on Pharmacognosy, Hibiscus sabdariffa, and Pomelo

Table 1: Key Components of Pharmacognosy

Component	Description
Medicinal Substances	Derived from plants, animals, and microorganisms
Excipients	Includes coloring agents, emulsifiers, and binders
Toxic & Hallucinogenic Plants	Studied for safety and effects
Phytochemistry	Study of plant-derived compounds
Biological Studies	Includes biosynthesis, biotransformation, and chemotaxonomy

Table 2: Nutritional Components of Hibiscus sabdariffa

Component	Presence in Hibiscus sabdariffa
Organic Acids	Citric, Malic, Tartaric, Allo-hydroxycitric acids
Vitamins	Beta-carotene, Vitamin C
Proteins	Present in seeds and leaves
Sugars	High total sugar content
Flavonoids	Rich in anthocyanins and phenolic acids

Table 3: Medicinal Properties of Hibiscus sabdariffa

Property	Effect
Antioxidant	Protects cells from free radicals
Antimicrobial	Fights bacterial and fungal infections
Antihypertensive	Helps regulate blood pressure
Anti-obesity	Aids in weight management
Hepatoprotective	Supports liver function
Cardioprotective	Protects against heart diseases

Table 4: Applications of Pomelo (Citrus maxima)

Application	Usage
Traditional Medicine	Used for digestive and metabolic disorders
Food Industry	Juice, jams, and preserves
Cosmetic Industry	Used in skincare and haircare products
Essential Oils	Aromatherapy and fragrance industries
Antioxidant Source	Used for health supplements

Table 5: Extracted Polysaccharides from Pomelo

Tissue Type	Extracted Polysaccharide
Pomelo Peel	Pomelo Peel Polysaccharides (PPPs)
Pomelo Seeds	Pomelo Seed Polysaccharides (PSPs)
Pomelo Pulp	Pomelo Pulp Polysaccharides (FPPs)
Segment Membranes	Segment Membrane Polysaccharides (SMPs)

Deep Science Publishing
https://doi.org/10.70593/978-93-49307-03-2

Chapter 2

Literature Review

2. Literature Review

The term "pharmacognosy" was first introduced between 1811 and 1815. Initially, it referred to "materia medica," which encompassed the knowledge of medicinal substances or pharmacology. The word is derived from two Greek terms: *pharmakon* (meaning "a drug") and *gignosko* (meaning "to acquire knowledge of") (Evans, 1996). Over time, pharmacognosy evolved to become the study of medicines derived from natural sources, including plants, animals, and microorganisms. This field focuses on the safety, purity, and efficacy of complex multi-compound products. The scope of pharmacognosy is extensive, covering the scientific exploration of natural substances and their derivatives. It involves the study of crude drugs, medicinal products. Pharmacognosy's roots extend back to ancient times. Evidence suggests that Neanderthals used medicinal plants such as yarrow and marshmallow over 60,000 years ago. Early humans identified the therapeutic properties of plants through observation, trial and error, accidental discoveries, curiosity, and the search for food. These practices led to the development of significant expertise in medicinal plants, eventually giving rise to individuals skilled in identifying, testing, and applying these natural remedies to treat illnesses.

Literature Review on Hibiscus flower

Hibiscus sabdariffa L. (commonly known as roselle, from the Malvaceae family) has been traditionally utilized in various ways, including as a food ingredient, in herbal beverages (both hot and cold), as a flavoring agent in the food industry, and as a component of herbal medicine. Research involving in vitro and in vivo studies, along with some clinical trials, has provided evidence for its potential health benefits, although many of these studies have examined extracts with limited phytochemical characterization. These extracts have demonstrated a range of effects, such as

antibacterial, antioxidant, nephroprotective, hepatoprotective, diuretic, lipid-regulating (anti-cholesterol), anti-diabetic, and anti-hypertensive properties.

Roselle (Hibiscus sabdariffa L.), known as "jamaica" in Spanish, is a perennial plant native to tropical and subtropical regions, including countries like China, Egypt, Indonesia, Mexico, Nigeria, Thailand, and Saudi Arabia. This plant has a rich history of diverse applications, particularly in culinary, botanical, floral, cosmetic, and medicinal contexts. Its medicinal uses are especially significant, as it exhibits diuretic, choleretic, analgesic, antitussive, antihypertensive, antimicrobial, immunomodulatory, hepatoprotective, antioxidant, and anticancer properties. These therapeutic benefits are primarily linked to its bioactive components, such as phenolic acids, flavonoids, anthocyanins, and various organic acids, including citric, hydroxycitric, hibiscus, tartaric, malic, and ascorbic acids. However, many reviews and meta-analyses exploring the therapeutic potential of Hibiscus sabdariffa L. compounds have insufficiently addressed the role of its organic acids within the extracts.

Hibiscus *rosa-sinensis*, commonly known as the China rose, belongs to the Malvaceae family and is widely recognized for its medicinal properties. This plant is traditionally used in several tropical regions to treat wounds, inflammation, fever, coughs, diabetes, bacterial and fungal infections, hair loss, and gastric ulcers. Phytochemical analysis has identified flavonoids, tannins, terpenoids, saponins, and alkaloids as the key bioactive compounds responsible for its therapeutic effects.

Recent studies have demonstrated that various extracts from different parts of *H. rosa-sinensis* exhibit multiple beneficial properties, including hypotensive, anti-pyretic, anti-inflammatory, anti-cancer, antioxidant, antibacterial, anti-diabetic, wound-healing, and abortifacient activities. Toxicity assessments have generally shown that most extracts do not induce toxic effects, even at higher doses, as confirmed by histological analysis. However, some extracts have been found to affect biochemical and hematological parameters.Further research is necessary to isolate specific phytochemicals and elucidate their precise mechanisms of action. This r\ view highlights the phytochemistry, pharmacology, and medicinal applications of *H. rosa-sinensis*, aiming to identify research gaps and assess its therapeutic potential through clinical trials.

Hibiscus species, belonging to the Malvaceae family, have been traditionally utilized in herbal medicine for addressing various ailments, including abscesses, liver disorders, cancer, cough, fatigue, digestive issues, fever, hangovers, cardiovascular diseases, neurological disorders, scurvy, and urinary tract infections. The antioxidants present in Hibiscus possess the ability to neutralize free radicals, which can otherwise harm cells and elevate the risk of inflammatory conditions such as metabolic syndrome, cancer, and heart disease.

This review examines the potential of *Hibiscus sabdariffa* L. (HS) in reducing risk factors for cardiovascular disease by assessing randomized clinical trial (RCT) findings in conjunction with ethnomedical, phytochemical, pharmacological, and safety data. Traditionally, HS decoctions and infusions, primarily derived from calyxes and occasionally leaves, are used in at least 10 countries to treat hypertension and hyperlipidemia, with no reported adverse effects. HS extracts are considered to have low toxicity, with an LD50 ranging from 2,000 to over 5,000 mg/kg/day, and no significant evidence of liver or kidney toxicity, except for potential hepatic effects at high doses. While HS possesses diuretic properties, it generally does not have a significant impact on electrolyte levels.

Animal studies consistently show that HS extract lowers blood pressure in a dose-dependent manner. RCTs indicate that daily intake of HS tea or extract significantly reduces both systolic (SBP) and diastolic blood pressure (DBP) in individuals with mild to moderate hypertension and type 2 diabetes. HS tea has been found to be as effective as Captopril in lowering blood pressure but less effective than Lisinopril. Additionally, HS extract has been shown to reduce total cholesterol, low-density lipoprotein cholesterol (LDL-C), and triglycerides in normolipidemic, hyperlipidemic, and diabetic animal models, while high-density lipoprotein cholesterol (HDL-C) remains largely unaffected. More than half of the RCTs suggest that consistent consumption of HS tea or extract benefits lipid profiles by lowering total cholesterol, LDL-C, and triglycerides while raising HDL-C levels.

The blood pressure-lowering and cholesterol-reducing effects of HS are primarily attributed to its high anthocyanin content, though polyphenols and hibiscus acid may also play a role. The most widely accepted mechanism suggests that anthocyanins function as antioxidants, inhibiting LDL-C oxidation and slowing the development of atherosclerosis, a major cardiovascular risk factor. While current research underscores the potential of HS extracts in managing hypertension and hyperlipidemia, further well-designed studies in both animal and human models, aligned with practical therapeutic applications, are required to develop evidence-based recommendations for widespread public health benefits. Hibiscus sabdariffa has long been appreciated both as a cultural drink and a traditional herbal remedy. Recent studies have thoroughly examined its potential therapeutic effects and mechanisms in managing chronic illnesses. This review assesses the health benefits of Hibiscus sabdariffa, with a focus on its impact on common chronic conditions. A thorough search of databases like PubMed, MEDLINE, Clinical Key, and CINAHL identified studies related to its active compounds, antioxidant and anti-inflammatory effects, and its role in treating conditions such as hypertension, hyperlipidemia, obesity, diabetes, and Alzheimer's disease.

The antihypertensive benefits of Hibiscus sabdariffa are linked to its ability to widen blood vessels, promote diuresis, inhibit the angiotensin-converting enzyme (ACE), reduce fat cell formation, lower heart rate, and reduce inflammation. Its cholesterol-lowering effects, which are dose-dependent, are associated with its antioxidant properties and the activation of AMP-activated protein kinase (AMPK) via phosphorylation. Additionally, it suppresses key transcription factors involved in fat cell formation, including peroxisome proliferator-activated receptor gamma (PPAR-γ), CCAAT/enhancer-binding protein alpha (C/EBP-α), and sterol regulatory element-binding protein-1c (SREBP-1c), aiding in the reduction of lipids.

As a hypoglycemic agent, Hibiscus sabdariffa enhances insulin sensitivity by inhibiting the phosphorylation of insulin receptor substrate-1 (IRS-1), showing effects similar to gliptins. Research also highlights its neuroprotective qualities, including its ability to reduce neuroinflammation in microglial cells exposed to lipopolysaccharides (LPS) by lowering pro-inflammatory cytokines such as interleukin-1 (IL-1), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α). Additionally, it protects against glucose-induced neuronal damage and boosts memory by preventing the formation of hyperphosphorylated tau proteins in mice brains.

Consuming hibiscus tea or its extracts regularly is linked to a reduced risk of chronic diseases, reinforcing its role as a functional food for health promotion and disease prevention. However, further clinical studies are needed to establish standardized dosages and confirm its long-term safety and effectiveness across various populations.

Literature Review on Pomelo fruit

Citrus maxima Merr., commonly referred to as Pomelo, belongs to the Rutaceae family and is recognized for its ethnomedicinal, pharmacological, and phytochemical importance. Traditional medicine has highlighted its use in managing conditions such as cough, fever, asthma, diarrhoea, ulcers, diabetes, and as a sedative. A variety of bioactive compounds, including polyphenols, terpenoids, sterols, carotenoids, vitamins, and amino acids, have been identified in C. maxima. The plant exhibits a wide range of biological activities, such as antioxidant, antimicrobial, anti-inflammatory, analgesic, anticancer, antidiabetic, anti-Alzheimer's, insecticidal, anxiolytic, hepatoprotective, antimalarial, and antiobesity effects. Further research is essential to uncover the detailed mechanisms of action of its extracts and compounds, paving the way for the development of effective medicines, herbal formulations, and functional food products**.** Pomelo (*Citrus maxima*), a member of the Rutaceae family, is one of the largest fruits within the citrus genus. It is available in various flesh colors, including red, pink, light pink, and

white. The fruit is rich in polyphenols, such as phenolic acids, flavonoids, anthocyanins, and tannins. Significant waste products from pomelo, including its peel, pomace, and seeds, contain bioactive compounds that offer health benefits. Key bioactive compounds in pomelo include hesperidin, narirutin, naringin, and their aglycone form, naringenin, which have long been recognized as the fruit's major constituents. Pomelo juice is an excellent source of vitamins A and C, while its peel contains high levels of protein, carbohydrates, and minerals. The cultivation and processing of pomelo and its byproducts present a sustainable opportunity for both the agricultural and food sectors. The waste materials, rich in essential bioactive compounds, hold considerable value for human health. This review discusses the latest developments regarding the nutritional benefits, bioactive properties, and health advantages of pomelo, emphasizing the potential to enhance consumer acceptance and promote its health-enhancing properties. The aim of this study was to investigate the engineering, physicochemical, and nutritional characteristics of various pomelo fruit varieties. Research Method: A one-way analysis of variance with three replications was employed to assess three pomelo cultivars—red, pink, and white—focusing on their engineering, physicochemical, and nutritional attributes. Findings: The results showed notable differences in the geometrical and gravimetric properties across the pomelo varieties. In terms of texture, the pink variety exhibited the highest puncture resistance at 20.19 N. Optical color analysis indicated that the white variety had the highest values. Fourier transform infrared spectroscopy identified functional compounds, suggesting the potential for developing a range of functional products. The analysis of physicochemical and nutritional properties revealed a variety of essential nutrients and minerals, including boron, magnesium, aluminum, silicon, phosphorus, potassium, iron, copper, and zinc, highlighting the fruit's high nutritional quality. This positions pomelo as a functional food ingredient with diverse potential applications in the food industry. Significant variation ($p<0.05$) was found in the physicochemical and nutritional properties among different parts of the pomelo varieties. Research Limitations: No limitations were reported. Originality/Value: Pomelo is an underutilized fruit, rich in bioactive compounds, with a strong nutritional profile and health benefits. Despite its impressive nutritional value, its utilization remains limited due to a lack of comprehensive information on its physicochemical, nutritional, and processing technologies. This study enhances the understanding of pomelo's properties, which could help inform its design, processing, storage, transportation, and product development, promoting its wider commercialization. Fruits and vegetables contain numerous bioactive compounds that contribute significantly to human health. Their nutritional value has increasingly attracted consumer interest, as they play a vital role in disease prevention. People primarily consume them for their nutritional benefits and quality, which are key factors influencing consumer preference and market potential.

Pomelo (*Citrus grandis* (L.) Osbeck), also referred to as pummelo, shaddock, or Chinese grapefruit, is categorized into common (white) and pigmented (pink) varieties. According to FAO data, global pomelo production reaches approximately 9.3 million metric tons, with China and the United States being the leading producers, accounting for around 5.0 and 0.5 million metric tons, respectively (FAOSTAT, 2019). In Southeast Asia and beyond, pomelo has gained popularity and is now among the top five most cultivated and consumed citrus fruits, alongside oranges, mandarins, lemons, and grapefruits. It has a sweet yet slightly acidic taste with a hint of bitterness. While studies have analyzed the volatile compounds in varieties such as Nakon and Chandler pomelo, the differences in phytochemical composition across various pomelo fruit parts remain largely unexplored.

Citrus fruit composition varies widely due to factors such as rootstock, fruit size, variety, ripeness, storage conditions, horticultural practices, and climate. As a result, nutrient content and composition fluctuate, making it challenging to establish definitive conclusions. Citrus fruits, particularly, are a major dietary source of β-cryptoxanthin, alongside other carotenoids and flavonoids.

Phytochemicals, including polyphenols found in plant-based foods, have gained attention due to their strong antioxidant activity and potential health benefits. These include anti-inflammatory, anticarcinogenic, antiatherogenic, antithrombotic, immune-enhancing, and vasodilatory properties. Flavonoids, a type of polyphenol, not only contribute to the flavor of many fruits and vegetables but also help plants cope with environmental stress. Considered secondary metabolites, flavonoids provide various health benefits when consumed. One well-known flavonoid in citrus fruits is naringin, which imparts grapefruit's characteristic bitterness.

The ripeness or maturity index of fruits plays a crucial role in determining their physical attributes (such as color, shape, size, and texture) and nutritional value. Studies have shown that antioxidant properties change at different stages of fruit ripening in species like olives, oranges, tomatoes, and pear jujubes. However, limited research exists on how polyphenol content correlates with soil properties and agricultural methods. Intensive farming, driven by economic considerations, often prioritizes rapid fruit growth in nutrient-rich soils, sometimes at the expense of higher secondary metabolite concentrations. Examining nutritional variations during fruit ripening can help determine the optimal harvesting period to ensure the best quality for both direct consumption and industrial applications. A better understanding of biochemical changes in fruits like medlar, as well as the chemistry behind phytochemical transformations and their physiological roles, can help enhance the sensory and nutritional benefits of polyphenols in the human diet. If these variations can be systematically mapped, it would allow for

an indirect estimation of citrus antioxidant content without requiring extensive laboratory analyses, facilitating the identification of harvest-ready trees.

Currently, there is a lack of data regarding changes in phytochemical content and total antioxidant activity during different developmental and maturation stages of pomelo fruit. This study aims to investigate phytochemical variations over two consecutive seasons in different parts of the pomelo, while also mapping key flavor-related compounds in its juice. The findings will offer valuable insights for the juice processing and pharmaceutical industries, helping to determine the ideal harvest time and the most beneficial fruit parts for bioactive compound extraction. Ultimately, these results could serve as guidelines for the food industry, supporting the production of high-quality foods and the incorporation of health-promoting components into daily diets. **[Da-Costa-Rocha, I., Bonnlaender, B., Sievers, H., Pischel, I., & Heinrich, M. (2014),Tusilowati, D. A., & Sugihartini, N. (2023), Lin, L. Y., Huang, C. Y., Chen, K. C., & Peng, R. Y. (2021).**

Deep Science Publishing
https://doi.org/10.70593/978-93-49307-03-2

Chapter 3

Pharmacognosy of Hibiscus Flower

3.1. Pharmacognosy of Hibiscus Flower:

Common names: Hibiscus, Jaba, Roselle, Jamaica flower, China rose etc.

Scientific name: Hibiscus sabdariffa Linn & Hibiscus rosa-sinesis.

Parts used: Flower petals.

Family: Malvaceae.

Active constituents: Anthocyanins, Flavonoids, Glycosides etc.

Geographical distribution: The plant is widely grown in tropics like Caribbean, Central America, India, Africa, Brazil, Australia, Hawaii, Florida and Philippines as a home garden crop **[Brown F, González J, Monan M]**.

Taxonomical classification [Macharia, J. M., Mwangi, R. W., Rozmann, N., Zsolt, K., Varjas, T., Uchechukwu, P. O., & Raposa, B. L. (2022)]:

Domain	**Eukaryota**
Kingdom	Plantae
Phylum	Spermatophyta
Subphylum	Angiospermae
Class	Dicotyledonae
Order	Malvales
Family	Malvaceae
Genus	Hibiscus
Species	Hibiscus rosa-sinensis, *Hibiscus sabdariffa*

Morphology: The roselle plant is known for its attractive foliage and flowers, capable of growing up to 2 meters tall. Different parts of the plant, including its leaves, seeds, fruits, and roots, are widely used in both the food and medicinal industries. The most

economically important feature of the roselle, however, is its bright red, fleshy, cup-shaped calyx, which surrounds the flower and holds significant commercial value **[Meftahizadeh, H., Ebadi, M. T., Baath, G. S., & Ghorbanpour, M. (2022)]**

Macroscopic and Microscopic Characteristics of Hibiscus sabdariffa: Macroscopic Characteristics

Size: Medium to large flowers, 8–10 cm in diameter.

Colour: Petals are pale yellow or pink with a deep red or purple centre ; calyces are bright red and fleshy.

Shape: Bell-shaped or funnel-shaped with five overlapping petals.

Texture: Smooth and delicate petals; firm and slightly sticky calyces.

Odor and Taste: Mild, tangy aroma, with calyces having a sour taste similar to cranberries.

Microscopic Characteristics Petals: Polygonal epidermal cells with a smooth cuticle. Calyces: To compact epidermal cells with thick walls and calcium oxalate crystals.

Therapeutic uses :

1. It is used in the treatment of Hypertension.
2. It is used to reduce Cholesterol.
3. It is used to play an important role in the treatment of anaemia particularly in immune-comprised HIV patients.
4. The leaves of *Hibiscus sabdariffa* have been shown to promote apoptosis in prostate cancer cell lines, effectively inhibiting tumour proliferation and growth.
5. Leaves of *Hibiscus sabdariffa* also show antihyperlipidemic effects. **[Raghu, K. (n.d.)., Garg, D., Shaikh, A., Muley, A., & Marar, T. (2012).,Vasavi, C. L., Jyothi, A. S., Sravani, P., Chand, T. P., Adil, S. K., Raja, R. R., & Baba, K. H. (n.d.).]**

Phytochemical constituents :

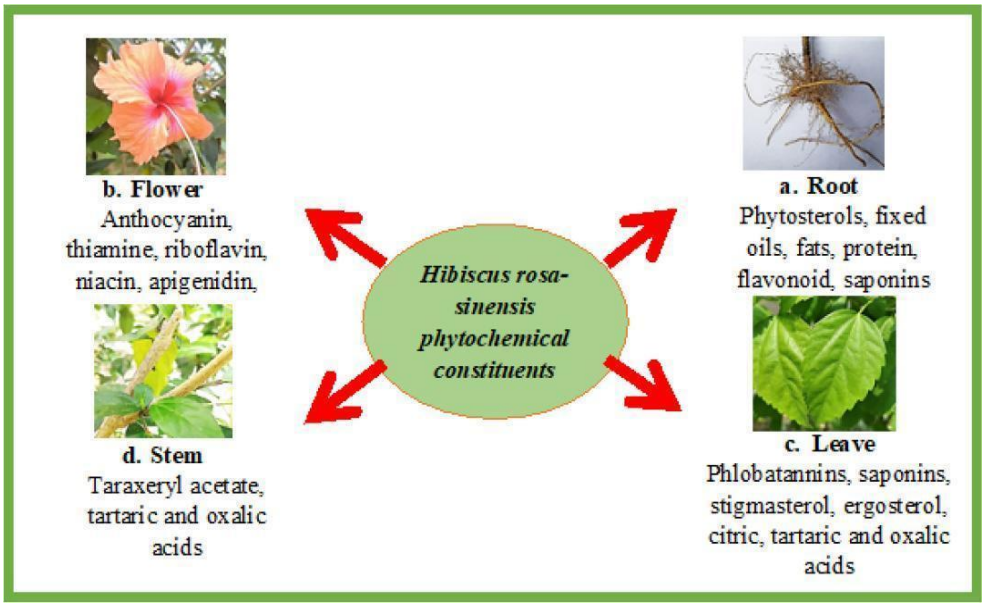

Figure No.3.1.1. Phytochemical constituents of *Hibiscus rosa sinensis*, *Hibiscus sabdariffa*

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Chapter 4

Pharmacognosy of Pomelo fruit

4.1. Pharmacognosy of Pomelo fruit:

Common name: Pomelo, Jamboa, Shaddock, Jeruk bali, Jambura etc.

Scientific name: *Citrus maxima.*

Family: Rutaceae.

Parts used: Peel & pulp.

Active constituents: vitamin C, flavonoids, and carotenoids. The compounds found in the peel of pomelo consist of flavonoids, coumarins, phenylpropanoids, phenolics, steroids, and essential oils.

Geographical distribution: The fruit, originally from Southeast Asia, is commonly known as "shaddock" in the Western world. The pomelo plant, a tropical fruit species native to Southeast Asia, produces fruit twice annually. It is commercially cultivated in countries such as Malaysia, Thailand, Vietnam, Indonesia, India, and China.

Taxonomical classification:

Table No.3.1 Taxonomical classification of *Citrus maxima*

Domain	**Eukaryota**
Kingdom	Plantae
Division	Tracheophyta
Class	Magnoliopsida
Order	Sapindales
Family	Rutaceae
Genus	Citrus
Species	Citrus maxima

Morphology:

The pomelo plant thrives in tropical lowland regions up to 400 meters above sea level, favouring temperatures between 25–32°C and receiving 1,500–2,500 mm of rainfall annually, with a dry spell lasting 3–4 months. Its fruit is large and spherical, ranging from 10–30 cm in diameter, with a thick outer rind composed of two layers: the flavedo(outer layer) and the albedo(inner layer of peel), which together make up about 30% of its weight. The flesh inside can be pink or white, offering flavours that vary from sweet to mildly tart.

Therapeutic uses :

1.The therapeutic properties of pomelo fruit including antioxidant, antiatherogenic, anti inflammatory, antimicrobial, anticancer effects.

2. the most used parts of pomelo in traditional medicine are: leaves (epilepsy, convulsion), flowers as sedative, fruits for (Asthma and Cough), rind can be used in vomiting and diarrhoea, while root and bark show good antimicrobial activity.

3. In traditional Chinese medicine, pomelo is used to treat flu, fatigue, wounds, coughs, phlegm, nausea, and congestion.

4.The fruit's peel can be used to repel mosquitoes and flies from food.

5.The essential oil obtained from pomelo fruit can be used in the industry for lotions, shampoos, disinfectants, and insecticides. Its essential oil can also be used to address, reduced strength, low stamina, inflammation, burns, acne, or skin disorders[15-16] **[Ahmad, A. A., Al Khalifa, I. I., & Abudayeh, Z. H. (2018)., Abiq, M. A., Sutrisno, S., & Marfuah, S. (2024)., Kourelatou, A., Chatzimitakos, T., Athanasiadis, V., Kotsou, K., Makrygiannis, I., Bozinou, E., & Lalas, S. I. (2024).]**

Deep Science Publishing
https://doi.org/10.70593/978-93-49307-03-2

Chapter 5

Extraction methods

5.1. Extraction methods of Hibiscus Sabdariffa flower:

5.1.1. Solvent Extraction:

Materials:

Dried hibiscus sabdariffa flowers, Solvent (e.g., ethanol, methanol, water), Mortar and pestle or blender, Filter paper, Funnel, Beaker, Rotary evaporator etc.

Procedure:

Preparation of Plant Material:
Drying: Thoroughly dry the hibiscus flowers to remove excess moisture.
Milling: Mill the dried flowers into a fine powder using a mortar and pestle or a grinder.

Solvent Extraction:

Solvent Selection: Choose a suitable solvent (e.g., ethanol, methanol, or water) based on the desired compounds' polarity.

Maceration:

To add the powdered plant material to a suitable container. Cover the material with the selected solvent. To allow the mixture to stand at room temperature, with occasional agitation, for several hours or overnight. Heat Extraction: Gently heat the mixture to accelerate the extraction process, but avoid excessive heat to prevent degradation of heat-sensitive compounds.
Filtration: To filter the mixture to remove plant debris.

Concentration:

Rotary Evaporation: To remove the solvent under reduced pressure to obtain a concentrated extract.

Natural Evaporation: To allow the solvent to evaporate naturally at room temperature.

Storage: Store the extract in a tightly sealed container, protected from light and heat.

5.1.2. Soxhlet Extraction:

Materials: Dried hibiscus sabdariffa flowers, Soxhlet extractor, Round-bottom flask, Condenser, Filter paper, Solvent (e.g., ethanol, methanol), Heating mantle, Rotary evaporator etc.

Procedure:

Preparation of plant materials:

Drying: Thoroughly dry the hibiscus flowers to remove excess moisture.

Milling: Mill the dried flowers into a fine powder using a grinder or mortar and pestle.

Extraction:

Solvent Selection: Choose a suitable solvent (e.g., ethanol, methanol) based on the desired compounds' polarity.

Assembly:

To place the powdered plant material in a thimble. To insert the thimble into the Soxhlet extractor. To filled the round-bottom flask with the selected solvent. Connect the Soxhlet extractor to the condenser.

Extraction:

Heat the solvent in the flask to boiling.
Solvent vapours rise, condense, and drip onto the plant material.
The solvent extracts compounds from the plant material.
The solvent-extract mixture siphons back into the flask.
This cycle repeats continuously.
Extraction Time: Typically, 6-8 hours of extraction is sufficient.

Concentration: Rotary Evaporation: Remove the solvent under reduced pressure to obtain a concentrated extract. Natural Evaporation: To allow the solvent to evaporate naturally at room temperature.

Storage: Store the concentrated extract in a tightly sealed container, protected from light and heat.

5.1.3. Ultrasound-Assisted Extraction (UAE):

This technique uses ultrasound waves to disrupt the plant cells and enhance the release of bioactive compounds into the solvent. This method is particularly effective for extracting bioactive compounds from plant materials, including hibiscus flowers.

Procedure:

Preparation:
Drying: Thoroughly dry the hibiscus flowers to remove excess moisture.
Milling: Mill the dried flowers into a fine powder using a grinder or mortar and pestle.

Extraction:

Solvent Selection: Choose a suitable solvent (e.g., ethanol, methanol, water) based on the desired compounds. Extraction Setup: To add the powdered plant material and the selected solvent to an ultrasonic bath or probe sonicator. To adjust the sonication time, temperature, and solvent-to-solid ratio as needed.

Sonication:

To apply ultrasound waves to the mixture.
The ultrasound waves disrupt plant cells, enhancing the release of bioactive compounds into the solvent.
Filtration: To filter the mixture to remove plant debris.

Concentration:

Rotary Evaporation: To remove the solvent under reduced pressure to obtain a concentrated extract.
Natural Evaporation: To allow the solvent to evaporate naturally at room temperature.
Storage: Store the concentrated extract in a tightly sealed container, protected from light and heat.

5.1.4. Microwave-Assisted Extraction (MAE):

Microwave-Assisted Extraction (MAE) is a rapid and efficient technique that uses microwave radiation to heat the solvent and plant material, accelerating the extraction process.

Preparation:

Drying: Thoroughly dry the hibiscus flowers to remove excess moisture.

Milling: Mill the dried flowers into a fine powder using a grinder or mortar and pestle.

Extraction:

Solvent Selection: Choose a suitable solvent (e.g., ethanol, methanol, water) based on the desired compounds.
Extraction Setup: Add the powdered plant material and the selected solvent to a microwave-safe vessel. Adjust the microwave power, irradiation time, and solvent-to-solid ratio as needed.

Microwave Irradiation:

To heat the mixture using microwave radiation. The microwave energy heats the solvent and plant material, accelerating the extraction process.

Filtration: Filter the mixture to remove plant debris.

Concentration:

Rotary Evaporation: To remove the solvent under reduced pressure to obtain a concentrated extract.

Natural Evaporation: To allow the solvent to evaporate naturally at room temperature.
Storage: Store the concentrated extract in a tightly sealed container, protected from light and heat.

5.2. Extraction methods of Pomelo fruit:

5.2.1. Maceration:

Steps: Preparation: To dry the desired parts of the fruit (such as peel, pulp, or seeds) and grind them into a fine powder.

Extraction: Submerge the powder in a solvent, such as ethanol, methanol, or water, and keep it at room temperature or slightly warm.

Separation: To filter the liquid to separate the extract from solid residues.

Concentration: To use methods like rotary evaporation or vacuum drying to remove the solvent and concentrate the extract.

Commonly used solvents: Ethanol, methanol, acetone, or combinations of these, with water as a co-solvent in some cases.

Applications: Ideal for isolating both water-soluble and lipid-soluble bioactive compounds, such as flavonoids, alkaloids, and phenolics.

5.2.2. Percolation Extraction

Steps:

To pack the powdered fruit material into a percolator, a device with a controlled outlet.

To add a solvent, allowing it to soak and flow slowly through the material.

To collect the extract until the solvent becomes saturated with the desired compounds.

Commonly used solvents: Ethanol, methanol, or acetone at varying concentrations.

Applications: Effective for extracting polar compounds, such as flavonoids and phenolic substances.

5.2.3. Soxhlet Extraction

Steps:

To place the dried, powdered fruit material in a thimble inside a Soxhlet extractor.

Heat the solvent (e.g., ethanol, hexane, or ethyl acetate) in a flask so it vaporizes, condenses, and repeatedly flows over the sample.

The process continues until the solvent fully extracts the desired compounds.

Commonly used solvents:

Ethanol/Methanol: That is best for polar compounds like flavonoids and phenolics.

Hexane: It is used for nonpolar substances, including essential oils and terpenes.

Applications: Suitable for obtaining a wide variety of bioactive compounds efficiently.

5.2.4. Ultrasound-Assisted Extraction (UAE)

Steps:

Add powdered fruit material to a container with a solvent (e.g., ethanol, methanol, or water).

To used ultrasonic waves to enhance solvent penetration and disrupt cell walls.

To filter the mixture and concentrate the extract.

Commonly used solvents: Water-ethanol or ethanol-methanol combinations.

Applications: Suitable for flavonoids, alkaloids, and phenolics.

5.2.5. Cold Solvent Extraction

Steps: To soak the dried fruit material or peels in a solvent at low temperatures (below 10°C). To stir or shake the mixture occasionally to enhance the extraction process. To filter the solution and concentrate the extract.Commonly used solvents: Ethanol, methanol, or acetone.

Applications: Ideal for extracting thermolabile antioxidants and phenolic compounds.

5.2.6. Pressurized Liquid Extraction (PLE)

Steps: To load the dried fruit material into an extraction vessel.
Heat and pressurize the solvent, allowing it to penetrate the plant material more effectively. To collect the extract after releasing the pressure.Commonly used solvents: Water, ethanol, or a combination of both.The CO_2 is then captured and reused, making the process both cost-effective and environmentally sustainable.

Applications: To produce high yields of phenolics, alkaloids, and limonoids. **[Kourelatou, A., Chatzimitakos, T., Athanasiadis, V., Kotsou, K., Makrygiannis, I., Bozinou, E., & Lalas, S. I. (2024).]**

Deep Science Publishing
https://doi.org/10.70593/978-93-49307-03-2

Chapter 6

Application of Pharmacological Properties of Hibiscus sabdariffa Flower and Pomelo Fruit in Cosmetics

6. Pharmacological Properties Relevant to Cosmetics with Hibiscus sabdariffa Flower:

6.1. In Malaysia the oil is used to produce scrubs and soaps18.

6.2. Pharmacological properties19

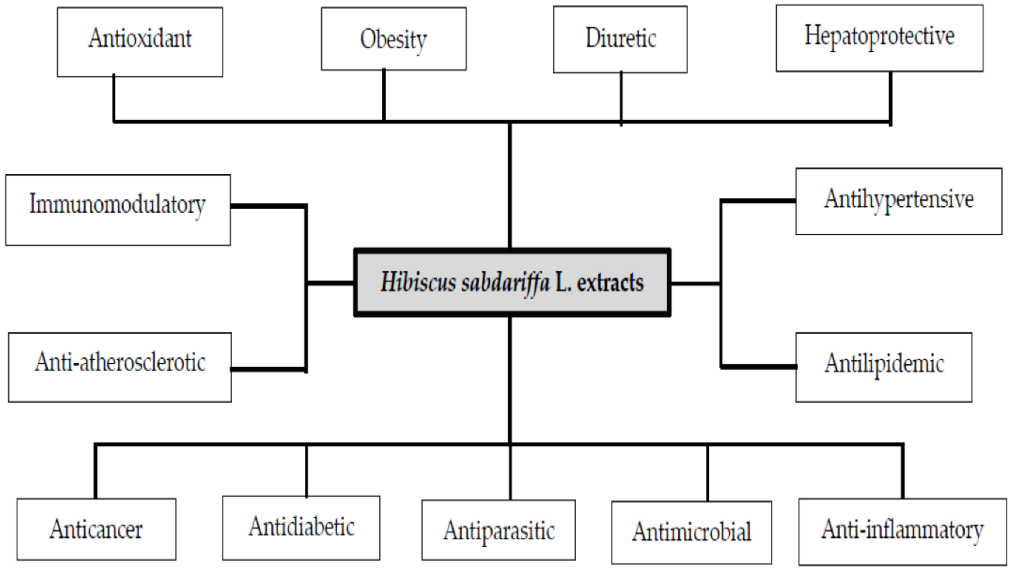

Figure No.6.1. Pharmacological properties of HS.

The flowers of Hibiscus sabdariffa (roselle) are valued in cosmetics for their rich bioactive compounds, offering various skin and hair care benefits:

6.2.1. Antioxidant Properties

Bioactive Elements: Rich in polyphenols, flavonoids (e.g., quercetin), anthocyanins (such as delphinidin-3-sambubioside and cyanidin-3-sambubioside), and ascorbic acid (vitamin C).

Cosmetic Applications: It shields the skin from oxidative stress and environmental damage. It reduces the appearance of fine lines and wrinkles associated with premature aging.It promotes a healthier, more radiant complexion.

6.2.2. Anti-inflammatory Effects

Active Components: Includes flavonoids, organic acids, and phenolic compounds.Cosmetic Applications: Calms skin irritation and reduces redness or puffiness. Beneficial for sensitive or acne-prone skin to help alleviate inflammation.

6.2.3. Antimicrobial Properties

Active components: Organic acids and phenolic substances.

Relevance to Cosmetics: It protects the skin and scalp from microbial growth.It supports acne treatments and alleviates scalp concerns like dandruff.

6.2.4. UV Protection

Main Components: Anthocyanins and flavonoids.

Cosmetic Benefits: It provides mild UV protection by absorbing harmful rays.

It reduces the impact of UV damage, such as pigmentation and sunburn.

6.2.5. Hair Care Benefits

Essential Nutrients: Rich in vitamins, minerals, and amino acids.

Advantages for Hair: Strengthens hair roots and prevents breakage.

It enhances hair shine and manageability.

It addresses scalp issues like dryness and itchiness.

6.2.6. Biological Activities of Hibiscus sabdariffa Calyxes with In Vitro and In Vivo Models.

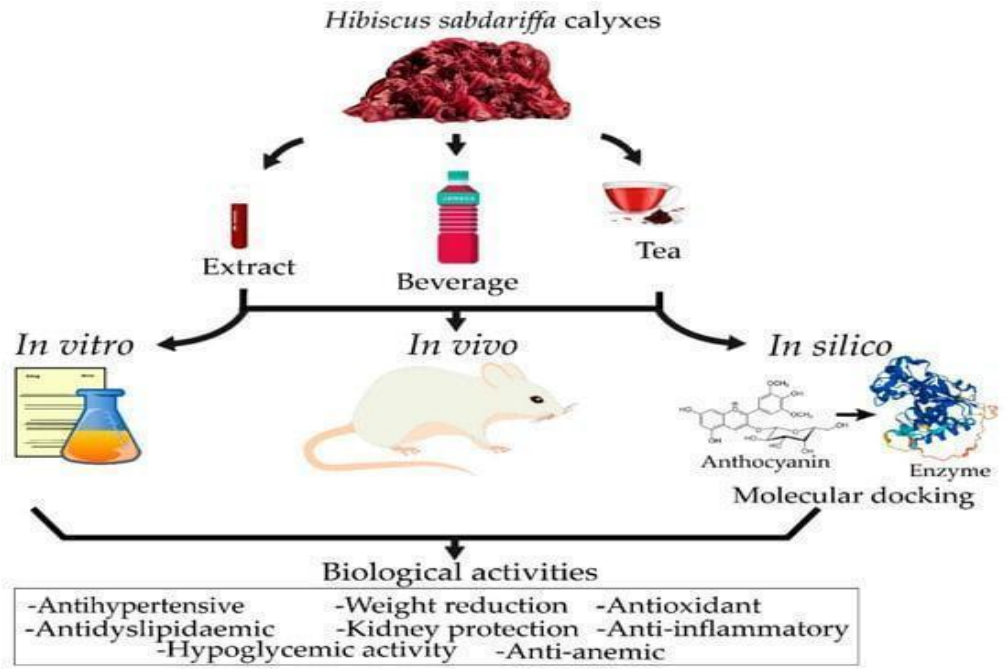

Figure No.6.2. Biological activities of Hibiscus sabdariffa by in vitro, in vivo, or in silico tests.

6.2.7. Biological Activities of Hibiscus sabdariffa Calyxes in Clinical Trials.

HS calyxes are widely used in non-pharmacological therapy to prevent or control diverse chronic non-communicable diseases associated with their antihypertensive, anti-dyslipidemic, hypoglycaemic, antianemic, nephroprotective, antioxidant, anti-xerostomic, and anti-inflammatory properties and body fat mass reduction effects (Figure 6.3). The flower extract is potentially used in ornamental skin care. **[Montalvo-González, E., Villagrán, Z., González-Torres, S., Iñiguez-Muñoz, L. E., Isiordia-Espinoza, M. A., Ruvalcaba-Gómez, J. M., Arteaga-Garibay, R. I., Acosta, J. L., González-Silva, N., & Anaya-Esparza, L. M. (2022)., Upadhyay, R. K. (2023).]**

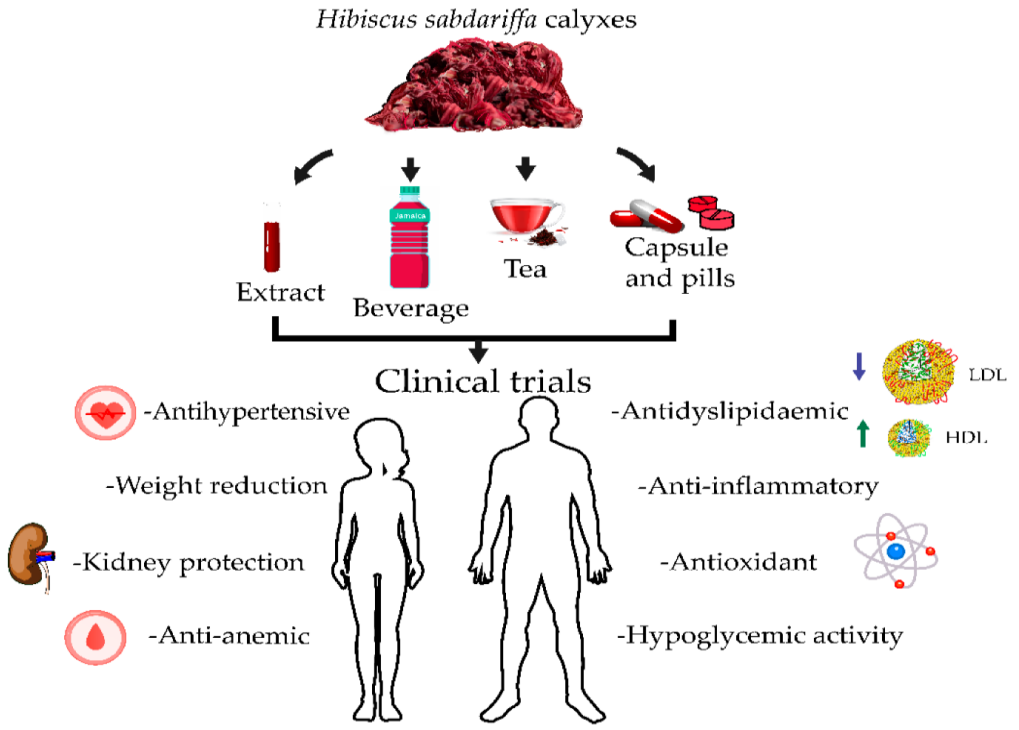

Figure 6.3. Beneficial effects of Hibiscus sabdariffa in humans.

7. Pharmacological Properties Relevant to Cosmetics Pomelo fruit:

In the cosmetic industry, this fruit has become notable due to its abundance of bioactive components. Below is an outline of its key properties and their relevance in cosmetic applications:

7.1. Antioxidant Benefits

How it Works: Pomelo is rich in vitamin C, flavonoids, and other antioxidant compounds that helps to protect the skin by neutralizing free radicals, a major cause of premature aging and environmental damage.

Applications in Cosmetics:

It is used in anti-aging formulations to minimize wrinkles and fine lines.

It shields skin from oxidative stress caused by pollutants and UV exposure.

7.2. Antimicrobial Properties

How it Works: Essential oils extracted from pomelo seeds and peels, including limonene, exhibit antimicrobial effects that combat bacteria and fungi.

Applications in Cosmetics:

It is used in acne treatment products.
It suitable for natural deodorants and as a preservative in organic formulations.

7.3. Skin Brightening Potential

How it Works: The natural presence of alpha-hydroxy acids (AHAs) and vitamin C in pomelo contributes to gentle exfoliation and reduces melanin production, promoting an even complexion.
Applications in Cosmetics:
It incorporated into skin-brightening creams and serums.
It reduces dark spots, pigmentation, and uneven skin tone.

7.4. Anti-Inflammatory Effects

How it Works: Compounds like bioflavonoids and limonoids found in pomelo help soothe skin inflammation and reduce redness.
Applications in Cosmetics:
It ideal for sensitive skin care products.
To effective in calming after-sun or soothing formulations.

7.5. Moisturizing and Hydrating Properties

How it Works: Pomelo contains natural sugars and polysaccharides that help retain moisture in the skin, enhancing hydration.
Applications in Cosmetics:
It is used in moisturizers, hydrating masks, and toners.
It prevents dehydration by strengthening the skin's natural barrier.

7.6. Exfoliation and Cleansing Action

How it Works: The citric acid in pomelo provides gentle exfoliation, removing dead skin cells and clearing clogged pores.
Applications in Cosmetics:
Key ingredient in exfoliating scrubs and cleansing products.
It promotes a smoother, more radiant skin texture.

7.7. Protection Against UV Damage

How it Works: Naringin, a bioflavonoid in pomelo peel, absorbs UV rays and reduces damage caused by sun exposure.

Applications in Cosmetics:
It enhances sunscreen formulations.
It reduces signs of photoaging such as pigmentation and loss of elasticity.

7.8. Hair and Scalp Health

How it Works: Loaded with vitamins A, C, and E, as well as essential minerals like zinc, pomelo supports hair growth and nourishes the scalp.
Applications in Cosmetics:
It included in shampoos and conditioners for shiny, healthy hair.
It helps reduce dandruff and soothes irritated scalps.

7.9. Refreshing Aroma and Sensory Appeal

How it Works: The citrusy essential oils of pomelo offer a fresh, uplifting fragrance, enhancing the sensory experience of cosmetic products.
Applications in Cosmetics:
It is used as a fragrance in perfumes, body sprays, and aromatherapy products.
It adds a refreshing touch to natural skincare formulations**. [Tocmo, R., Pena-Fronteras, J., Calumba, K. F., Mendoza, M., & Johnson, J. J. (2020)., Lin, L. Y., Huang, C. Y., Chen, K. C., & Peng, R. Y. (2021)., Sharma, S., Singh, B., Kaur, G., Srivastava, Y., & Sandhu, R. S. (2024).]**

Deep Science Publishing
https://doi.org/10.70593/978-93-49307-03-2

Chapter 7

Application of Hibiscus sabdariffa Flower and Pomelo Fruit in Cosmetics

7.1. Application of Hibiscus flower in Cosmetic formulation:

7.1.1. Lotion:

How to Make Rosella Flower Petal Extract Lotion :The process of making rosella flower petal extract lotion starts with weighing all the ingredients. These are divided into two parts: the oil phase and the water phase.

1. Preparing the Oil Phase: Stearic acid and cetyl alcohol are melted one after the other at 70°C.

2. Preparing the Water Phase: Methylparaben is dissolved in hot water at 70°C.Glycerine is then added, followed by triethanolamine, keeping the temperature at 70°C throughout.

3.Mixing the Phases: The oil phase is poured into the water phase and mixed using a magnetic stirrer. The mixture is stirred at a constant speed for 3 minutes until a smooth, uniform lotion base is formed.

4.Final Steps: Rosella petal extract and calliandra honey are added to the lotion base. The mixture is stirred again until it becomes fully homogeneous **[Fadli, J. C., & Lasanudin, R. I. (2024)].**

7.1.2. Lipstick:

Lipstick is used to beautify the lips with vibrant colours, keep them moisturized, highlight their natural appeal, and disguise bad lip shape.

Lipstick Preparation Process:

Prepare the Dye Solution: To start by pouring castor oil into a container to create Mixture 1. Add Rosella flower extract to the castor oil and mix thoroughly to dissolve the dyes.

Melt the Base Ingredients:

To combine lanolin, cetyl alcohol, beeswax (Cera alba), and paraffin wax in a separate container. To melt these ingredients using a water bath until they are fully liquefied.

Combine Oil Phase and Base:

To gradually pour the melted base into Mixture 1 while continuously stirring to prevent hardening and to ensure uniform blending.

Add Preservatives and Fragrance:

Mix in propylparaben (as a preservative) and oleum rosae (as a fragrance). Heat the mixture briefly over the water bath until it is slightly liquefied to ensure smooth pouring.

Moulding the Lipstick:

To pour the prepared mixture into moulds and allow it to cool and solidify.

Quality Testing: Once the lipstick is fully set, evaluate its quality and properties using the following tests:-

Organoleptic Test: To assess its appearance, colour, and fragrance.

pH Test: To check the product's pH level for safety.

Homogeneity Test: To ensure uniform texture and colour.

Topical Test: To examine how the lipstick applies to the skin.

Melting Point Test: To determine the temperature at which the lipstick melts.

Strength Test: To assess its structural durability.

Irritation Test: To evaluate for potential skin irritation **[Nurcahyo, H., & Febriyanti, R. (2020)].**

7.1.3. Making Lip balm:

Making Rosella Flower Powder:

Dried Rosella flower Simplicia (Hibiscus sabdariffa L.) is cut into small pieces and then grinded to form a powder.

Preparation of Rosella Flower Ethanol Extract:

Approximately 600 grams of rosella flower powder (Hibiscus sabdariffa L.) was macerated in 1800 mL of 96% ethanol. The powder was soaked for three days with occasional stirring, and the residue was washed with an appropriate amount of solvent. The mixture was then filtered to separate the liquid extract into a clean container. The liquid extract obtained from maceration was concentrated using a rotary evaporator at approximately 70°C for about 5 hours, operating at a speed of 100 rpm. Since the concentrated extract was suspected to still contain residual ethanol, further evaporation was carried out using a water bath. This step ensured the production of a viscous rosella flower extract free from ethanol.

Anthocyanin Qualitative Test :

The extract was dissolved in distilled water and subjected to qualitative testing. A positive indication of anthocyanins was observed when the extract turned blue-green upon the gradual addition of NaOH. When HCl was added and the mixture heated to 100°C, the colour remained red.

Making Lip balm:

Each ingredient was weighed according to the required proportions. Beeswax and paraffin wax were heated in a porcelain cup over a water bath at 80°C. Lanolin was heated separately under the same conditions. Meanwhile, nipagin and BHT were dissolved in olive oil until fully mixed. The oil mixture was then combined with the melted lanolin and wax while stirring to ensure a uniform blend. Strawberry flavouring was added next and mixed thoroughly until homogeneous. The mixture was removed from the water bath and combined with rosella flower extract, pre-dissolved in propylene glycol. Once the mixture became slightly thick and homogeneous, it was poured into lip balm containers and allowed to cool and solidify at room temperature.

Lip Balm Quality Tests:

1.Organoleptic Test

The lip balm was evaluated for its colour, shape, texture, and scent using sensory analysis through the five senses.

2.pH Test

The pH of the lip balm was measured using a calibrated pH meter. The electrode was rinsed with distilled water and dried with tissue before use. A 1% sample solution was prepared by dispersing 1 g of lip balm in 100 mL of distilled water. The electrode was immersed in the solution, and the pH meter was allowed to stabilize to display the pH

value. The acceptable pH range for lip balm is 3.8–4.7, aligning with the natural pH of the lips.

3.Melting Point Test

The melting point of the lip balm was determined by observing its behaviour upon heating. A capillary tube (1 mm diameter) was filled with the lip balm and placed in a melting point apparatus. The temperature at which the sample began to melt was recorded. A good-quality lip balm is expected to have a melting point between 65–75°C.

4.Physical Stability Test

The prepared lip balm was tested for physical stability in a climatic chamber maintained at 40 ± 2°C with 75 ± 5% relative humidity. The stability test was conducted over one month, with weekly observations for changes in pH and organoleptic properties **[Tusilowati, D. A., & Sugihartini, N. (2023)].**

7.2. Application of Pomelo fruit in Cosmetic formulation:

7.2.1. Polyherbal face scrub gel: Benefits of herbal scrub gel

To keep flawless skin, To removes skin flakes, To remove dead cells from the skin, To remove acne scars

Materials and methods:Materials: Red dragon fruit seed, Pomelo peel, Neem, Triethanolamine, Sodium lauryl sulphate, Carbopol 940, Methylparaben, Propylene glycol, Rose water.

Equipment's: Beaker, Measuring Cylinder, Mortar pestle.

Instruments: Digital balance, Sieves, Mechanical Stirrer.

Methodology

Herbal ingredients used in formulation

1. Dragon fruit seed: Seleniferous undatus

Dragon fruit seeds were collected from the fruit of dragon fruit, which was purchased from the market. It is thoroughly washed, cleaned, dried in oven and powdered. After that kept in an air tight container.

Kingdom: Plantae
Phylum: Tracheophyta Clade: Rosids
Class: Magnoliopsida

Order: Sapindales
Family: Rutaceae
Genus: Citrus
Species: Maxima.

2. Pomelo peel: Citrus maxima

Pomelo peel were collected from the fruit of pomelo found in local areas, it is collected, cut to small pieces, dried and powdered, stored in an air tight container.

Kingdom: Plantae

Clade: Rosids

Class: Magnoliopsida

Order: Sapindales

Family: Rutaceae
Genus: Citrus
Species: Maxima.

3. Neem leaves: Azadirachta indica

Neem leaves were collected locally, as they are widely available in most areas. The collected leaves were washed, cleaned, and shade-dried. They were then grounded using a mixer and sieved to obtain a fine powder, which was stored in an airtight container.

Kingdom: Plantae
Phyllum: Spermatophyta
Clade: Angiospermae
Class: Magnoliopsida (Dicotyledons)
Order: Sapindales
Family: Meliaceae
Genus: Azadirachta
Species: Indica.

Preparation of polyherbal face scrub gel Weighing:

The herbal powders prepared for formulating the polyherbal face scrub gel are weighed individually. All the powders are arranged conveniently near a digital balance. Each ingredient is carefully weighed using the digital balance to ensure accurate measurements.

Sieving:

The fine, homogenous powder mixture is sieved manually to achieve uniform particle size. The herbal powder mixture, consisting of Neem and Pomelo, is placed on a mesh sieve with an aperture size between 44 and 80. The sieve is tapped gently at the sides, with a paper sheet placed underneath to collect the sieved fine powder, resulting in a uniformly fine texture.

Mixing: The accurately weighed Dragon fruit seeds are mixed using the trituration method, which involves gently rubbing the seeds in a mortar and pestle. All the herbal ingredients are then combined in ascending order of their quantities to ensure thorough mixing.

Storage: The powdered herbal ingredients are transferred to an airtight container for proper storage, preserving their quality and preventing contamination.

Formulations of polyherbal face scrub gel

The polyherbal face scrub gel was formulated as planned. Three batches (SG1, SG2, and SG3) were prepared with slight variations in the ingredient concentrations. All batches were thoroughly evaluated to determine the optimal formulation.

Formulation table

Table no.7.2.1: Formulation of Polyherbal scrub gel.

Sl. No.	Ingredients	SG1	SG2	SG3
1.	Dragon fruit	2%	2%	2%
2.	Pomelo	1%	1.5%	2%
3.	Neem	1%	1%	1%
4.	Carbapol940	1.5%	2%	3%
5.	Methyl paraben	0.2%	0.15%	0.05%
6.	Triethanolamine	1%	2%	2%
7.	Propylene glycol	2%	1.5%	2%
8.	Sodium lauryl sulphate	3%	2.5%	2%
9.	Rose water	2drops	2-3drops	2drops
10.	Distilled water	Qs	Qs	Qs

Procedure of polyherbal scrub gel

Preparation of Gel Base:

The gel base was prepared by first taking the required quantity of water in a beaker. A measured amount of Carbopol 940 was gradually added to the water using a homogenizer and allowed to hydrate overnight. The mixture was then stirred with a mechanical stirrer until a uniform gel consistency was achieved. A pre-weighed amountof methylparaben, dissolved in water, was added to the gel and stirred thoroughly. Propylene glycol and sodium lauryl sulphate were incorporated in measured quantities, followed by the addition of triethanolamine to adjust the pH to the desired level. Finally, a few drops of rose water were added for fragrance. This process resulted in the preparation of the scrub gel.

Evaluation of polyherbal scrub gel

The prepared polyherbal face scrub gel was evaluated for various parameters. It includes-

Organoleptic Evaluation

Colour: The colour of the scrub gel formulation was observed as green and evaluated through manual inspection.

Odor: The fragrance of the scrub gel formulation was assessed by applying it to the hands and smelling the scent of the incorporated perfume.

Consistency: The consistency of the formulation was evaluated to check the texture and homogeneity, focusing on attributes like stiffness, greasiness, and softness when applied to the skin.

Texture: The texture of the scrub gel was tested by pressing a small quantity between the thumb and index finger.

pH: The pH of the polyherbal face scrub gel formulation was determined using a digital pH meter.

Spreadability: The spreadability of the polyherbal face scrub gel, a critical factor influencing its ease of application, was evaluated by assessing how well the gel spreads across the skin surface.

Washability: The washability of the scrub gel was tested directly on the skin, which had been prepped and cleaned with water.

Viscosity: The viscosity of the polyherbal face scrub gel was measured using a Brookfield viscometer.

Irritancy Test: The irritancy test was performed by applying the prepared polyherbal face scrub gel to a marked 1-square-centimeter area on the left dorsal surface of the skin. The

area was monitored periodically for any signs of irritation **[Achankunju, A., Nishad, A., Arya, S., & Minos, M. S. (n.d.)].**

7.2.2. Pomelo peel ointment(PPO):

Materials Required

Pomelo Peel Ethanolic Extract: 93 grams (prepared by air-drying, extraction, and rotary evaporation).

Base Ingredients

Propylene glycol: 62.38 mL
Cetyl alcohol: 130.95 grams
Methylparaben: 0.119 grams
Propylparaben: 0.083 grams
White petrolatum: 547.62 grams
Sodium lauryl sulphate: 0.15 grams (dissolved in water)
Distilled Water: As required for dissolving certain ingredients.

Equipment

Hot plate or water bath
Beaker (500 mL and 1 L capacity)
Glass stirrer or magnetic stirrer
Weighing scale
Thermometer
Mixing bowl or homogenizer
Container for storage (airtight and sterilized).

Procedure

The pomelo peel extract was prepared by combining 125 grams of air-dried pomelo peel with 125 mL of ethyl alcohol, storing the mixture in a tightly sealed container for two weeks, and then extracting it through rotary evaporation. The PPO formulation was created by mixing 62.38 mL of propylene glycol with water, 130.95 grams of cetyl alcohol, 0.119 grams of methylparaben, 0.083 grams of propylparaben, 547.62 grams of white petrolatum, and 0.15 grams of sodium lauryl sulphate dissolved in water, along with 93 grams of the pomelo peel ethanolic extract. A 12.5% concentration was used in the preparation of the PPO **[Chiu, A. L., & Visitacion, L. (2019)].**

Or,

Pomelo Peel Extract Preparation:

Combined 125 grams of air-dried pomelo peel with 125 mL of ethyl alcohol. Stored the mixture in a tightly sealed container for two weeks. Extracted the solution using rotary evaporation.

PPO Formulation:

Mixed 62.38 mL of propylene glycol with water. Then added 130.95 grams of cetyl alcohol, included 0.119 grams of methylparaben and 0.083 grams of propylparaben, added 547.62 grams of white petrolatum, and 0.15 grams of sodium lauryl sulphate dissolved in water, along with added 93 grams of pomelo peel ethanolic extract.

Concentration: A 12.5% concentration was used in the PPO preparation.

Table No.7.1. Rosella flower petal extract lotion formulation

Ingredient	Purpose	Quantity
Stearic acid	Thickening agent	Measured as required
Cetyl alcohol	Emulsifier	Measured as required
Methylparaben	Preservative	Measured as required
Glycerine	Humectant	Measured as required
Triethanolamine	pH Adjuster	Measured as required
Rosella petal extract	Active ingredient	Measured as required
Calliandra honey	Moisturizer	Measured as required

Table No.7.2. Lipstick Ingredients and Formulation

Ingredient	Purpose	Quantity
Castor oil	Solvent for dyes	Measured as required
Rosella flower extract	Coloring agent	Measured as required
Lanolin	Emollient	Measured as required
Cetyl alcohol	Emulsifier	Measured as required
Beeswax	Structure provider	Measured as required
Paraffin wax	Structure provider	Measured as required

Propylparaben	Preservative	Measured as required
Oleum rosae	Fragrance	Measured as required

Table No.7.3. Lip Balm Ingredients and Formulation

Ingredient	Purpose	Quantity
Beeswax	Base	Measured as required
Paraffin wax	Base	Measured as required
Lanolin	Moisturizer	Measured as required
Olive oil	Emollient	Measured as required
Nipagin	Preservative	Measured as required
BHT	Antioxidant	Measured as required
Strawberry flavoring	Fragrance	Measured as required
Rosella flower extract	Active ingredient	Measured as required
Propylene glycol	Solvent	Measured as required

Table No.7.4. Lip Balm Quality Tests

Test	Purpose	Expected Result
Organoleptic Test	Appearance, color, texture	Uniform
pH Test	pH level measurement	3.8–4.7
Melting Point Test	Stability check	65–75°C
Physical Stability Test	Shelf stability	No changes observed

Table No.7.5. Polyherbal Face Scrub Gel Ingredients

Ingredient	Purpose
Dragon fruit seed	Exfoliant
Pomelo peel	Skin brightener
Neem	Antibacterial
Carbopol 940	Gel base
Methylparaben	Preservative

Triethanolamine	pH Adjuster
Propylene glycol	Moisturizer
Sodium lauryl sulphate	Surfactant
Rose water	Fragrance

Table No.7.6. Polyherbal Face Scrub Gel Formulation Comparison

Ingredient	**SG1 (%)**
Dragon fruit seed	2
Pomelo	1
Neem	1
Carbopol 940	1.5
Methylparaben	0.2
Triethanolamine	1
Propylene glycol	2
Sodium lauryl sulphate	3
Rose water	2 drops
Distilled water	Qs
Ingredient	**SG1 (%)**
Dragon fruit seed	2
Pomelo	1
Neem	1
Carbopol 940	1.5
Methylparaben	0.2
Triethanolamine	1
Propylene glycol	2
Sodium lauryl sulphate	3

Table No.7.7. Polyherbal Face Scrub Gel Quality Tests

Test	**Evaluation Method**
Organoleptic Test	Visual and sensory inspection
pH Test	Digital pH meter
Spreadability	Manual spread test
Washability	Direct application on skin
Viscosity	Brookfield viscometer
Irritancy Test	Skin patch test

Table No.7.8. Polyherbal Face Scrub Gel Quality Tests

Step	**Description**
Extraction	Pomelo peel air-dried, soaked in ethanol, and evaporated

Mixing	All ingredients combined and homogenized
Step	Description
Extraction	Pomelo peel air-dried, soaked in ethanol, and evaporated
Formulation	Prepared at 12.5% concentration

Table No.7.9. General Cosmetic Testing Procedures

Test	Description
Organoleptic	Checks color, texture, scent
pH Test	Ensures compatibility with skin
Melting Point Test	Determines stability
Spreadability Test	Evaluates application ease
Irritancy Test	Detects potential skin reactions

7.3. Application in Facial Cream with Lamellar Crystals of Pomelo Fruits Extract

Evaluation of Antioxidant Properties of Tabtimsiam Pomelo Peel Extract (*Citrus maxima* Burm.f. Merr) and Its Use in Facial Cream with Lamellar Crystals. This study explores the antioxidant potential of Tabtimsiam pomelo peel extract (*Citrus maxima* Burm.f. Merr) and its incorporation into a facial cream formulated with lamellar crystal technology. The extract's total phenolic content (TPC), determined using the Folin-Ciocalteu reagent assay, was measured at 48.59 ± 0.66 mg GAE/g extract, while the total flavonoid content (TFC), assessed via the aluminum chloride colorimetric method, was 184.70 ± 7.04 mg QE/g extract. Antioxidant activity was evaluated using the DPPH radical scavenging assay, yielding an IC50 value of 63.24 ± 16.57 mg/mL. A facial cream containing lamellar crystals was developed and compared to a base formulation. The results demonstrated that the lamellar crystal-based cream exhibited superior stability. Microscopic examination under polarized light revealed a uniform Maltese cross pattern, confirming the formation of well-structured lamellar systems.The effectiveness of the facial cream infused with Tabtimsiam pomelo peel extract at concentrations of 0.1%, 0.2%, and 0.3% w/w was assessed over four weeks. Among the formulations, the 0.2% w/w extract cream provided the highest moisturizing effect, with a conductivity measurement of 247 ± 1.26 μS. Additionally, skin analysis using a Dino-Lite camera indicated enhanced skin texture, giving it a glassy appearance.

Lamellar Crystals of Extract: An Innovative Advancement in Skincare

Lamellar crystals are structured lipid bilayers that closely resemble the natural lipid organization of the skin. When combined with botanical extracts, they significantly enhance the stability, absorption, and efficacy of active ingredients in skincare

formulations. This advanced technology facilitates the efficient delivery of plant-derived compounds into the skin, providing long-lasting hydration, antioxidant protection, and targeted therapeutic benefits.

Formation of Lamellar Crystals with Extracts Understanding Lamellar Crystals

Lamellar crystals create layered structures skin to the lipids found in the stratum corneum (the outermost layer of the skin). These structures consist of alternating layers of water and lipids, which contribute to:

- Enhanced formulation stability
- Superior moisture retention
- Controlled and prolonged release of active ingredients

Incorporating Plant Extracts into Lamellar Crystals

Botanical extracts such as pomelo peel extract, green tea, aloe vera, and centella asiatica contain flavonoids, polyphenols, and essential vitamins that benefit the skin. These extracts are integrated into lamellar systems via encapsulation or emulsification, ensuring:

- Protection of delicate active compounds from oxidation and degradation
- Improved penetration into the skin for enhanced effectiveness
- Gradual, sustained release to maximize benefits over timeAdvantages of Lamellar Crystal-Infused Extracts in Skincare

Increased Stability of Active Ingredients: Botanical extracts are susceptible to oxidation and breakdown when exposed to external factors such as light, heat, or air. The lamellar crystal structure acts as a protective barrier, maintaining the potency of active ingredients for extended periods.

Superior Hydration and Moisture Retention: Due to their lipid-like arrangement, lamellar crystals help botanical extracts penetrate deep into the epidermis, effectively locking in moisture and minimizing transepidermal water loss (TEWL). This makes them particularly beneficial for dry and sensitive skin types.

Enhanced Absorption and Targeted Delivery: Traditional emulsions often fail to deliver active ingredients beyond the skin’s surface, reducing their overall effectiveness. In contrast, lamellar crystal formulations enable a controlled release of antioxidants, vitamins, and anti-inflammatory compounds, ensuring deeper penetration and prolonged skin benefits.

Lightweight, Non-Greasy Texture: Unlike heavy, oil-based creams, skincare formulations using lamellar crystals have a lightweight consistency that absorbs rapidly into the skin without clogging pores. This makes them suitable for all skin types, including oily and acne-prone skin.

Enhanced Effectiveness of Natural Extracts : Botanical extracts, enriched with polyphenols, flavonoids, and essential nutrients, exhibit heightened bioactivity when incorporated into lamellar structures. The benefits include:

- Antioxidant protection – Neutralizing free radicals to prevent skin aging
- Anti-inflammatory effects – Reducing redness, irritation, and inflammation
- Skin regeneration – Boosting collagen production for improved elasticity and repair

Applications in Skincare and Cosmetics

Anti-Aging and Deep Hydration Creams: Lamellar crystal-based formulations infused with plant extracts provide long-lasting hydration while delivering anti-aging benefits, such as reducing the appearance of wrinkles and fine lines.

Brightening and Hyperpigmentation Solutions: Extracts like pomelo peel, licorice root, and vitamin C work synergistically within lamellar systems to brighten the complexion, even out skin tone, and diminish dark spots more effectively.

Soothing and Skin Barrier Repair Creams: Products designed for sensitive or irritated skin can leverage lamellar crystal technology to incorporate anti-inflammatory plant extracts (e.g., centella asiatica, chamomile), offering gentle yet long-lasting skin relief.

Sunscreen and UV Protection : Lamellar structures also improve the stability of UV filters, ensuring that antioxidant-rich plant extracts (such as green tea extract and resveratrol) provide extended protection against UV-induced skin damage.

Lamellar crystal technology represents a breakthrough in botanical extract delivery for skincare, offering greater stability, enhanced penetration, and prolonged effectiveness. By replicating the skin's natural lipid structure, these innovative formulations provide superior hydration, improved skin protection, and advanced therapeutic benefits, making them a cutting-edge development in cosmetic science. **[Mayomhin, P., & Ma-in, B. (2024)]**

7.4. Pectin: Extraction Methods, Properties, and Applications in Drug Delivery and Biomedical Science

Pectin is a naturally occurring structural polysaccharide found in plants. It is primarily extracted from fruit waste using aqueous acidic, basic, or organic solvents with relatively simple equipment. To improve extraction efficiency and shorten processing time, advanced techniques such as microwave-assisted and ultrasound-supported methods have been introduced.

From a structural perspective, pectin, particularly rhamnogalacturonan, is composed of *d*-galacturonate and *l*-rhamnose, with side chains of *d*-galactose, *l*-arabinose, and *d*-xylose. Its key physicochemical properties, including solubility, gelling behavior, and complexing ability, are determined by factors such as its degree of branching, esterification level (methoxy/ethoxy), and the number of monomeric units in its backbone.

Beyond its traditional applications, pectin demonstrates promising benefits in nutraceuticals, particularly for its anti-obesity and cholesterol-lowering effects. Additionally, it contributes to environmental applications by aiding in heavy metal removal and exhibiting radioprotective properties. Medically, pectin serves as a coagulant and has been recognized for its antidiarrheal, antiulcer, and anticancer properties.

In biomedical research, pectin is widely utilized as a drug delivery carrier, particularly for colon-targeted therapies. It also serves as a structural template for the fabrication of nanomaterials such as colloidal dispersions, nanoemulsions, multiple emulsions, nanocapsules, nanofibers, and nanotubes, all designed to improve drug delivery efficiency.

Pectins in Pomelo: Structure, Extraction, and Applications

Pectin is a naturally occurring polysaccharide found in the cell walls of fruits, including pomelo (Citrus maxima). As a natural gelling, stabilizing, and emulsifying agent, pectin has numerous applications in the food, pharmaceutical, and cosmetic industries. Pomelo peels, a byproduct of fruit processing, are an excellent source of high-quality pectin, making them a sustainable and valuable resource.

Composition and Structure of Pomelo Pectin

Pectin is primarily made up of galacturonic acid units and can be classified based on its degree of esterification (DE):

- High-methoxyl pectin (HMP) – Forms gels in the presence of sugar and acid

- Low-methoxyl pectin (LMP) – Requires calcium ions to form gels

Pomelo-derived pectin typically contains:

- Rhamnogalacturonan regions, which include d-galacturonate and l-rhamnose
- Branched side chains with d-galactose, l-arabinose, and d-xylose
- Variable degrees of esterification, influencing its functional properties

The unique structural composition of pomelo pectin provides strong gelling and stabilizing abilities, making it highly valuable in various applications.

Extraction of Pectin from Pomelo Peels

Pectin is extracted from pomelo peels using different solvent-based and advanced extraction techniques:

Traditional Extraction Methods

- Acidic aqueous extraction – Uses weak acids (e.g., citric acid, hydrochloric acid) to break down the plant cell walls and release pectin
- Basic and organic solvent extraction – Less commonly used due to potential degradation of pectin structure

Advanced Extraction Techniques

To improve yield and quality, modern methods are employed:

- Microwave-assisted extraction (MAE) – Increases extraction efficiency and reduces processing time
- Ultrasound-assisted extraction (UAE) – Enhances cell disruption for better pectin recovery
- Enzymatic extraction – Uses enzymes to selectively break down unwanted components, preserving pectin's natural structure

Pomelo pectin extracted through these methods has high purity, better solubility, and improved functional properties, making it ideal for industrial applications.

Functional Properties and Applications of Pomelo Pectin

Pharmaceutical and Nutraceutical Applications

Pomelo pectin has significant health benefits:

- Anti-obesity and cholesterol-lowering effects – Binds to dietary fats and cholesterol, aiding in weight management and heart health
- Prebiotic potential – Promotes gut health by serving as a food source for beneficial gut bacteria
- Heavy metal detoxification – Binds with heavy metals, aiding in their removal from the body

Biomedical and Drug Delivery Applications

- Wound healing – Forms biodegradable films for wound dressings
- Controlled drug release – Used in nanoparticles, hydrogels, and encapsulation systems for targeted drug delivery
- Cancer therapy – Exhibits potential anticancer properties by modulating immune responses and inhibiting tumor growth

Cosmetics and Skincare

- Moisturizer and stabilizer – Enhances the texture and stability of lotions, creams, and serums
- Anti-aging formulations – Improves hydration and elasticity due to its water-binding properties
- Lamellar crystal technology – Enhances absorption of bioactive compounds in skincare formulations

Pomelo-derived pectin is a versatile and valuable biopolymer with applications spanning food, pharmaceuticals, cosmetics, and biomedical industries. Its unique structural properties, excellent gelling ability, and health benefits make it a sustainable and functional ingredient in modern formulations. With advancements in extraction techniques and nanotechnology, pomelo pectin continues to gain attention as a natural, eco-friendly alternative in various industrial applications. **[Sangeeta, A., Gopalakrishnan, K., & Mishra, P. (2024)]**

7.5. Hibiscus Flower Face Spray: Antioxidant and Anti-Aging Potential

Beauty, particularly skincare, is a key concern for women, leading to the widespread use of various cosmetic products in Indonesia. Among these, face sprays are a popular choice due to their multiple benefits, including protection against free radicals from UV rays, prevention of premature aging, and hydration for dry skin. Antioxidants, when applied topically in cosmetic formulations, tend to be more effective than when taken orally.

One promising natural ingredient for skincare is the hibiscus flower, which is rich in flavonoids—compounds known for their potent antioxidant properties. These antioxidants help shield the skin from free radical damage, improve hydration, and enhance circulation, making hibiscus an excellent addition to anti-aging skincare products.

Research Overview

This study, conducted as an experimental analysis, focused on developing an ethanol-based hibiscus flower face spray in varying concentrations of 0.1%, 0.3%, 0.5%, and 0.7%. The formulations underwent comprehensive evaluations, including:

- Physical quality assessment
- User preference tests
- Irritation potential analysis
- Antioxidant activity measurement
- Anti-aging effectiveness testing

The anti-aging results were statistically analyzed using SPSS software with a parametric ANOVA test.

Optimal Face Spray Formulation

Among the four tested concentrations, the 0.5% hibiscus extract formulation emerged as the best choice, demonstrating:
Stable organoleptic properties (appearance, texture, and fragrance)
pH compatibility with the skin (ranging from 5 to 7.26)
Good spreadability without coarse particles or clumps
Stability over 28 days at room temperature (25°C)
Durability in a six-cycle stability test
No signs of skin irritation

Antioxidant Activity

Formulations with 0.1% and 0.3% hibiscus extract exhibited moderate antioxidant activity. Higher concentrations of 0.5% and 0.7% demonstrated strong antioxidant effects, making them more effective in neutralizing free radicals and protecting the skin from oxidative damage.

Anti-Aging Effectiveness

All face spray formulations displayed anti-aging benefits, indicating that hibiscus extract plays a crucial role in reducing visible signs of aging, such as fine lines, wrinkles, and skin dullness.The hibiscus-based face spray proved to be a promising skincare formulation, offering antioxidant protection, hydration, and anti-aging effects. The 0.5% extract concentration provided the best balance between efficacy, stability, and user safety, making it an ideal choice for cosmetic applications.

Face Spray: A Refreshing Skincare Essential

Face sprays have become a staple in skincare routines, offering hydration, protection, and rejuvenation in a convenient mist form. They provide immediate skin refreshment while delivering essential nutrients, antioxidants, and soothing agents. Depending on their formulation, face sprays can help combat dryness, free radical damage, premature aging, and irritation caused by environmental factors.

Key Benefits of Face Sprays

Hydration Boost – Helps maintain skin moisture, preventing dryness and flakiness.
Protection Against Free Radicals – Antioxidant-rich sprays defend against UV rays and pollution, reducing oxidative stress.
Anti-Aging Effects – Certain ingredients promote collagen production, reducing fine lines and wrinkles.
Soothing and Calming – Ideal for sensitive and irritated skin, especially when infused with botanical extracts like aloe vera or hibiscus.
Refreshing Sensation – Instantly cools and revitalizes the skin, making it perfect for hot climates.

Formulation Components

A high-quality face spray typically includes:

- Water or Hydrosols – The base, often infused with floral waters (e.g., rose water, chamomile hydrosol).

- Humectants – Such as hyaluronic acid or glycerin, which attract moisture to the skin.
- Botanical Extracts – Including hibiscus, green tea, or cucumber, offering antioxidant and soothing properties.
- Essential Oils or Vitamins – Like vitamin C, vitamin E, or niacinamide, which brighten and protect the skin.
- Preservatives – To ensure product safety and longevity.

Specialized Face Sprays

Antioxidant Face Sprays : Formulated with vitamin C, green tea, or hibiscus to fight aging and environmental stressors.

Hydrating Face Mists : Enriched with aloe vera, hyaluronic acid, and glycerin for deep

moisturization.Calming Sprays : Infused with chamomile, lavender, or centella asiatica for sensitive and irritated skin.

Setting Sprays : Designed to enhance makeup longevity while providing skin benefits. Face sprays are a versatile and effective skincare product, offering hydration, protection, and nourishment in a single spritz. Whether used for daily refreshment, antioxidant protection, or anti-aging benefits, they play a key role in modern beauty routines.

Table No.7.10. Face Spray Formulation Table

Ingredient	Function	Percentage (%)	Amount (mL) (for 100 mL)
Purified Water	Base solvent for dilution & hydration	70%	70 mL
Hydrosol (Rose/Lavender/Chamomile)	Soothing & toning properties	10%	10 mL
Glycerin	Humectant, locks in moisture	5%	5 mL
Hyaluronic Acid (1% solution)	Deep hydration & plumping effect	3%	3 mL
Hibiscus Extract (or Green Tea Extract)	Antioxidant, anti-aging, brightening	5%	5 mL
Niacinamide (Vitamin B3)	Evens skin tone, strengthens barrier	3%	3 mL

D-Panthenol (Vitamin B5)	Hydrating, soothing, promotes healing	2%	2 mL
Preservative (Geogard/Optiphen/Leucidal Liquid)	Prevents microbial growth	1%	1 mL
Essential Oil (optional, e.g., Lavender/Tea Tree)	Adds fragrance & skin benefits	0.5%	0.5 mL
pH Adjuster (Citric Acid/Sodium Hydroxide)	Balances pH to skin-friendly level (5-6)	As needed	As needed

Table No.7.11. Preparation Steps

Step	Process
1	Dissolve purified water, hydrosol, glycerin, hyaluronic acid, and niacinamide in a sterilized beaker.
2	Add hibiscus extract (or green tea extract) and mix thoroughly.
3	Incorporate D-Panthenol and preservative, ensuring complete dissolution.
4	Adjust pH to 5-6 using citric acid (to lower) or sodium hydroxide (to raise pH).
5	Add essential oil (optional) using a solubilizer like Polysorbate-20 for even dispersion.
6	Stir well and transfer into a sterilized spray bottle using a funnel.

7.6. Hair care products from Hibiscus

A plant in the Malvaceae family, hibiscus is well known for its amazing skincare properties. This shrubby plant, which originated in Africa, is now found in tropical and subtropical areas all over the world, including China, India, Sudan, and Malaysia. A significant ingredient in cuisine, cosmetics, and pharmaceutical compositions, hibiscus is grown for its flowers, leaves, stems, seeds, and roots. It greatly improves skin health since it is full of vital nutrients like protein, calcium, copper, iron, magnesium, potassium, zinc, and vitamins A, B6, C, E, and K. In addition to its aesthetic value,

hibiscus has potent antibacterial, antigenotoxic, antidiabetic, and anti-inflammatory qualities. These qualities have a calming and soothing effect on the mind in addition to aiding in the fight against numerous health issues.Natural Hair Care with Hibiscus

Hibiscus (*Hibiscus rosa-sinensis* and *Hibiscus sabdariffa*) is rich in essential nutrients that promote strong, healthy hair. Packed with vitamins (A, C, and E), amino acids, and antioxidants, it helps strengthen hair, reduce hair fall, delay premature graying, and improve scalp health. Below are simple, all-natural recipes for Hibiscus Hair Oil, Hair Mask, Shampoo, and Hair Rinse to nourish and revitalize your hair.

Hibiscus Hair Oil – Boosts Growth & Scalp Health

Ingredients:

1 cup fresh or dried hibiscus flowers and leaves
1 cup coconut oil / olive oil / sesame oil
1 teaspoon fenugreek seeds (optional, enhances hair growth)

Method:

1. Crush hibiscus flowers and leaves into a fine paste.
2. Warm the oil on low heat and add the hibiscus paste.
3. Simmer for 5–10 minutes, then add fenugreek seeds.
4. Remove from heat and let it cool.
5. Strain and store in a clean glass bottle.
6. Massage into the scalp twice a week for best results.

2. Hibiscus Hair Mask – Deep Conditioning & Strengthening

Ingredients:

5–6 hibiscus flowers (or 2 tablespoons hibiscus powder)
5 hibiscus leaves (optional)
2 tablespoons yogurt (moisturizes and softens hair)
1 tablespoon aloe vera gel (soothes the scalp)
1 teaspoon honey (locks in moisture)

Method:

1. Blend hibiscus flowers, leaves, and yogurt into a smooth paste.
2. Stir in aloe vera gel and honey; mix well.
3. Apply evenly to the scalp and along hair strands.
4. Leave for 30–45 minutes, then rinse with mild shampoo.

5. Use once a week for soft, nourished hair.

3. Hibiscus Shampoo – Controls Hair Fall & Gently Cleanses

Ingredients:

6–8 hibiscus flowers
10 hibiscus leaves
2 tablespoons aloe vera gel
½ cup liquid castile soap / rice water (gentle cleanser)
1 teaspoon coconut or almond oil

Method:

1. Blend hibiscus flowers and leaves with a little water into a fine paste.
2. Add aloe vera gel, castile soap, and oil; mix well.
3. Store in a bottle and shake before use.
4. Apply to wet hair, massage gently, and rinse with lukewarm water.
5. Use twice a week for healthy, voluminous hair.

4. Hibiscus Hair Rinse – Enhances Shine & Fights Dandruff

Ingredients:

5–6 hibiscus flowers
2 cups water
1 tablespoon apple cider vinegar (optional, balances scalp pH)

Method:

1. Boil hibiscus flowers in water for 10 minutes.
2. Let it cool and strain the liquid.
3. Mix with apple cider vinegar if desired.
4. Use as a final rinse after shampooing.

Hibiscus-based hair care products provide a natural, chemical-free way to nourish, strengthen, and protect hair. These DIY treatments are gentle, effective, and suitable for all hair types, making them a great alternative to commercial hair products.

7.7. Sustainable Dye Production from Hibiscus sabdariffa for Eco-Friendly and Allergy-Resistant Textiles

Environmental pollution is a pressing global issue, with industrial chemical usage contributing significantly to environmental degradation. Even after treatment, industrial effluents often contain trace elements that can harm ecosystems. As a sustainable alternative, enzyme extraction through natural methods offers a promising solution for dye production, reducing pollution while promoting environmental conservation for future generations.

Hibiscus sabdariffa (L.) is a rich source of anthocyanins, whose accumulation can be enhanced through callus formation and increased sucrose concentration. The anthocyanin pigments were extracted using acidified ethanol, and the resulting dye was analyzed via GC–MS screening. When applied in textile dyeing, various properties influenced the final color, depending on the fabric type. Additionally, the color of anthocyanin pigments varied with pH levels, demonstrating adaptability to different environmental conditions.

Notably, natural dyes derived from *Hibiscus sabdariffa* offer hypoallergenic properties, making them a safer alternative to synthetic dyes, which often contain harsh chemicals that can trigger allergic reactions and skin sensitivities. By incorporating plant-based dyes into textile production, the industry can reduce its environmental footprint while promoting healthier, skin-friendly fabrics for consumers.

Importantly, natural dyes derived from *Hibiscus sabdariffa* offer a safer alternative to synthetic dyes, which often contain harsh chemicals that can trigger allergic reactions and skin irritations. By using plant-based dyes in textile production, manufacturers can create allergy-resistant fabrics that are gentler on the skin, promoting consumer health while also reducing the environmental impact of textile manufacturing.

Preparation of Hibiscus Natural Dye for Textile Applications

Hibiscus flowers, particularly from *Hibiscus sabdariffa* and *Hibiscus rosa-sinensis*, are rich in anthocyanins, flavonoids, and organic acids, making them excellent natural dyes. These dyes produce shades ranging from pink, red, purple, and even blue, depending on pH conditions and mordants used.

Materials Required:

Fresh or dried hibiscus flowers (*Hibiscus sabdariffa* or *Hibiscus rosa-sinensis*)
Distilled water
Acidified ethanol (optional, for enhanced pigment extraction)
Mordants (such as alum, iron sulfate, vinegar, or salt)
Stainless steel or non-reactive pot

Heat source (stove or hot plate)
Strainer or cheesecloth
pH modifiers (lemon juice for acidic, baking soda for alkaline)

Extraction Process:

Collection & Preparation of Raw Material

Collect fresh hibiscus flowers and rinse thoroughly to remove dirt. If using dried flowers, ensure they are free from chemicals. Chop the flowers into smaller pieces for better pigment release.

Dye Extraction

Water Extraction (Gentle & Eco-Friendly Method)

Add fresh (1:5 ratio) or dried (1:10 ratio) hibiscus flowers to distilled water. Simmer at low to medium heat (60–80°C) for 45–60 minutes. Avoid boiling to preserve pigment integrity. Let the mixture cool and strain the liquid to obtain the dye extract. Ethanol Extraction (Stronger Pigment Release) Soak hibiscus petals in acidified ethanol (ethanol with 1% citric acid or vinegar) for 24–48 hours at room temperature. Stir occasionally for better pigment diffusion. Strain the mixture to collect the dye solution.

Dyeing Process: Fabric Preparation (Mordanting)

Pre-treat fabrics by soaking them in a mordant solution (e.g., alum for brighter shades, iron sulfate for darker tones, or vinegar for color enhancement) for 30–60 minutes. Rinse and dry before dyeing.

Dye Application

Submerge the fabric in the hibiscus dye bath. Heat gently (below 80°C) for 30–60 minutes, stirring occasionally for even coloration. Allow the fabric to soak in the dye bath for several hours or overnight for deeper shades.

Fixing & Finishing

Remove the fabric, rinse with cold water, and air dry in the shade to prevent color fading.

Adjust pH to alter dye color:

Acidic (lemon juice/vinegar) → Enhances red and pink hues.

Alkaline (baking soda/lime water) → Turns blue, purple, or green.

Hibiscus natural dye provides a sustainable, biodegradable, and hypoallergenic alternative for textile dyeing. It offers vibrant, pH-sensitive colors and can be used with different mordants to achieve a variety of shades.

7.8. Pomelo (Citrus maxima) as a Source of Natural Dye for Sustainable Textile Production

With rising concerns over environmental pollution and allergic reactions caused by synthetic dyes, the textile industry is turning to natural alternatives. Pomelo (*Citrus maxima*), a citrus fruit rich in bioactive compounds, offers a sustainable and skin-friendly source of natural dye. Pomelo peels and pulp contain flavonoids, tannins, and carotenoids—pigments known for their vibrant hues and antioxidant properties. These compounds can be extracted using eco-friendly solvents like acidified ethanol or water-based methods. The resulting dye produces shades ranging from pale yellow to deep orange, depending on the pH level and fabric type.

Benefits of Pomelo-Based Natural Dyes:

Eco-Friendly & Biodegradable – Unlike synthetic dyes, pomelo dyes break down naturally, reducing environmental impact. Hypoallergenic & Skin-Safe – Free from harsh chemicals, these dyes minimize allergic reactions and skin irritations.

Antimicrobial Properties – Pomelo extracts contain bioactive compounds that may enhance fabric durability and freshness.
pH-Sensitive Color Variations – The pigments respond to different pH levels, allowing for a range of natural shades.

Preparation of Pomelo (Citrus maxima) Natural Dyes for Textile Applications

Pomelo fruit, particularly its peel and pulp, contains natural pigments such as flavonoids, carotenoids, and tannins that can be extracted and used as eco-friendly dyes. Below is a step-by-step guide to preparing natural dyes from pomelo:

Materials Required:

Fresh pomelo peels and/or pulp
Distilled water
Acidified ethanol (optional, for enhanced extraction)

Mordants (such as alum, iron sulfate, or vinegar)
Stainless steel pot or glass container
Heat source (stove or hot plate)
Strainer or cheesecloth
pH modifiers (lemon juice for acidic, baking soda for alkaline)

Extraction Process:

Collection & Preparation of Raw Material

Wash and peel the pomelo fruit. Cut the peel into small pieces to increase the surface area for extraction. The pulp can also be used, but the peel contains higher concentrations of colorants.

Dye Extraction

Water Extraction (Mild & Eco-Friendly Method) Add the pomelo peels to a pot with distilled water (1:5 ratio of peels to water). Simmer for 45–60 minutes at low to medium heat (avoid boiling, as excessive heat may degrade the pigments). Let the mixture cool, then strain the liquid to obtain the dye extract. Ethanol Extraction (Stronger Pigment Release)

Soak pomelo peels in acidified ethanol (ethanol with 1% citric acid or vinegar) for 24–48 hours at room temperature. Stir occasionally for better pigment diffusion. Strain the mixture to collect the dye solution.

Dyeing Process:

Fabric Preparation (Mordanting)

Pre-treat fabrics by soaking them in a mordant solution (e.g., alum, iron sulfate, or vinegar) for 30–60 minutes to enhance dye absorption and colorfastness. Rinse and dry before dyeing.

Dye Application

Submerge the fabric in the extracted pomelo dye. Heat gently (below 80°C) for 30–60 minutes, stirring occasionally for even coloration. Let the fabric sit in the dye bath for several hours or overnight for deeper shades.

Fixing & Finishing

Remove fabric, rinse with cold water, and air dry in the shade to prevent color fading.

For pH-dependent color variations, modify the dye bath:

Acidic (lemon juice/vinegar) → Enhances yellow-orange hues.
Alkaline (baking soda) → Produces deeper brown or muted tones.
Pomelo-derived natural dyes offer a sustainable, hypoallergenic, and biodegradable alternative for textile coloring. This eco-friendly approach reduces environmental pollution while producing unique shades that vary based on fabric type, mordants, and pH adjustments.

Deep Science Publishing
https://doi.org/10.70593/978-93-49307-03-2

Chapter 8

Conclusion

8. Conclusion:

The analysis of *Hibiscus sabdariffa* flower reveals its potential as a beneficial component in cosmetic applications, thanks to its wealth of bioactive compounds such as anthocyanins, flavonoids, organic acids, and vitamins. These natural elements contribute to various advantages, including antioxidant support, enhanced skin hydration, brightening properties, anti-inflammatory effects, and mild exfoliation. The adaptability of hibiscus flower makes it ideal for use in products like lotion, lipstick and lip balm. This research underscores its value as a sustainable and natural alternative to synthetic components, aligning with the growing trend toward plant-based cosmetic solutions.

The pharmacognostic analysis of pomelo (*Citrus maxima* or *Citrus grandis*) reveals its significant potential in cosmetic applications. With a rich composition of beneficial compounds such as vitamin C, flavonoids, limonoids, and essential oils, pomelo offers properties that help protect the skin, reduce inflammation, and combat harmful microorganisms. Its main cosmetic advantages include anti-aging, skin-brightening, exfoliating, and hydrating effects. Additionally, pomelo-based formulations are generally safe, gentle on the skin, and align with sustainable practices by repurposing parts like the peel and seeds. These characteristics make pomelo a valuable ingredient for environmentally friendly and innovative cosmetic products like creams, masks, scrubs, and moisturizers.

Deep Science Publishing
https://doi.org/10.70593/978-93-49307-03-2

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