VALORISATION OF COCONUT SPROUT

BY

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TAVANUR – 679 573, MALAPPURAM

KERALA, INDIA

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PROJECT REPORT

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGNEERING AND FOOD TECHNOLOGY, TAVANUR, MALAPPURAM -679573

KERALA, INDIA

2024-2025

DECLARATION

We hereby declare that this project report, entitled "**VALORISATION OF COCONUT SPROUT**," is a bonafide record of our project work during the project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship, or similar title of any other university or society.

Place: Tavanur

Date: 16-01-2025

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CERTIFICATE

Certified that this project report entitled **"VALORISATION OF COCONUT SPROUT"** is a record of project work done jointly ANJANA K (2021-06-001), APARNA M P (2021-06-002), ANEESHA CELIN K S (2021-06-003), JUSWIN SAJI (2021-06-004) and ARYA T P (2021-06-005) under my guidance and supervision and that it has not previously performed the basis for award us of any degree, diploma, associateship, fellowship to them.

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CHAPTER I

INTRODUCTION

This chapter outlines the significance of coconut (Cocos nucifera) as a vital crop in tropical and subtropical regions, tracing its historical importance, cultivation, and diverse uses. The introduction discusses the role of coconuts in ancient trade and their adaptability to various environments. The unique attributes of the coconut palm, from its nutritional and economic value to its versatility in producing food, drink, construction materials, and fuel, are explored.

A dedicated section highlights coconut embryos, or sprouts, emphasizing their formation, nutritional benefits, and potential as a delicacy in regions like Kerala. However, challenges like declining cultivation in Kerala, competition from other states, and the underutilization of sprouts are detailed. Innovative technologies are needed to process sprouted coconuts and promote their marketability.

Finally, the chapter identifies research gaps, such as the undervaluation of coconut embryos in Indian markets, and frames objectives aligned with the Coconut Development Board's mission to enhance value addition in coconut processing, focusing on properties, drying methods, and applications in products like wine.

1.1. Introduction

Coconut (*Cocos nucifera*) has played a crucial role in human history, especially in tropical and subtropical regions. The spread of coconuts is closely tied to ancient maritime trade routes, as coconuts were highly valued for their nutritional content, water, and ability to grow in various coastal conditions (Gunn *et al.*, 2011). Coconuts were first domesticated for food, drink, and shelter. The ability of coconuts to float in saltwater for extended periods allowed them to naturally drift to new shores, where they sprouted and grew (Foale *et al.*, 2020). Today, coconuts are cultivated in over 80 countries worldwide, with Indonesia, the Philippines, and India being the largest producers (Gunn et al., 2011, Beveridge *et al.*, 2022).

Coconut belongs to the family *Arecaceae* (palm family), and its scientific name is *Cocos nucifera*. It is the only species in the genus *Cocos*. The family *Arecaceae* includes many other types of palms, but the coconut palm is unique in its ability to provide such a diverse array of products, from food and drink to building materials and fuel (Ghosh, 2015). The coconut palm can be divided into two: Coconut Fruit/ Seed and coconut tree. The young coconut fruit contains contain a clear liquid known as tender coconut water, which is consumed for hydration

and health benefits (Azra *et al.*, 2023). The flesh of mature coconuts can be eaten fresh or dried (known as copra), and is used to extract coconut oil, an important commodity in cooking and cosmetic industries. The fibrous husk is used to make coir (a material used in ropes, mats, and brushes), while the hard shell can be used as fuel, in handicrafts, or to create activated charcoal (Stelte *et al.*, 2023). The various parts of tree like the leaves can be used for weaving mats, roofing materials, and baskets while the trunk provides wood for building and construction. Coconuts are a critical source of income for many tropical regions. The coconut oil is used extensively in cooking and cosmetics (Grass Ramírez *et al.*, 2023). In recent years, coconut water has gained global popularity as a health drink due to its hydrating properties and rich nutrient profile (Azra et al., 2023). As coconut water is a natural electrolyte-rich drink, it is often used after exercise or if a person suffers from illness (Azra et al., 2023). Coconut oil, when consumed in moderation, may support cardiovascular health due to its healthy fats, though it's still a topic of debate (Schwingshackl and Schlesinger, 2023). Lauric acid, found in coconut oil, has antimicrobial and antifungal properties (Schwingshackl and Schlesinger, 2023), making it useful in skincare and health products.

1.2. Coconut Sprout

The coconut embryo, also known as the "coconut apple" or "coconut sprout," is a lesser-known yet highly fascinating part of the coconut. The coconut embryo is usually round or oval-shaped and can vary in size, but it typically takes up a large portion of the hollow space inside the coconut(Manju *et al.*, 2021). Some describe it as having a slightly nutty, milky taste (Manju et al., 2021). It forms inside a mature coconut once the seed begins to germinate, transforming the liquid endosperm (coconut water) into a spongy, soft structure (Manju et al., 2021). This is essentially the plant's embryo, or the first stage of a new coconut palm’s life cycle. This process typically happens when the coconut falls from the tree and remains on the ground, allowing the natural germination process to begin. The embryo serves as a nutrient reserve for the growing seedling. During this stage, the embryo draws on the stored energy in the coconut water and meat to sustain its growth until the seedling develops roots and can draw nutrients from the soil (Beveridge et al., 2022). This highlights its importance not only in the coconut’s growth process but also in sustaining the propagation of coconut palms across tropical ecosystems (Beveridge et al., 2022).

Like coconut meat, the embryo is rich in medium-chain fatty acids (MCFAs), which are easier to digest and provide a quick energy source. It contains essential vitamins like vitamin C and

minerals such as potassium, magnesium, and calcium. The coconut embryo is a good source of fiber, promoting healthy digestion and helping regulate blood sugar levels (Manivannan *et al.*, 2018). Though not as widely consumed as coconut water or oil, coconut embryos are considered a delicacy in some tropical regions, where people savor them for their subtle sweetness and unique texture (Mu *et al.*, 2024).

Over the past few decades, there has been a decline in coconut cultivation in Kerala due to the conversion of agricultural land for urbanization, housing, and commercial purposes (Karunakaran and Gangadharan, 2014). This reduction in coconut farming directly affects the availability of coconut sprouts, limiting supply to the market. The labor-intensive nature of coconut cultivation, combined with a growing labor shortage in rural areas, has contributed to the decline in production (Hebbar *et al.*). Many younger generations are moving away from traditional farming, leading to fewer coconut trees being planted and maintained (Girdziute *et al.*, 2022).

Kerala faces competition from other Indian states like Tamil Nadu and Karnataka, where coconut production is more efficient due to better agricultural practices, lower labor costs, and higher productivity. This competition limits Kerala's market share in both the coconut and coconut sprout industries. In addition to domestic competition, Kerala also faces competition from cheaper international coconut imports, which further depress local prices and reduce profitability for farmers (George and Kuruvila, 2022).

Sl No.	Countries	AREA ('000 Hectares)	Production (Million nuts)	Productivity (Nuts/ha)
1	F.S.Micronesia	18.00	60.00	3,333
2	Fiji	64.00	257.00	4,016
3	Guyana	10.00	92.00	9,200
4	India	2,150.00	21,288.00	9,901
5	Indonesia	3,402.00	14,140.00	4,156
6	Jamaica	16.00	129.00	8,063
7	Kenya	85.00	301.00	3,541
8	Kiribati	31.00	145.00	4,677
9	Malaysia	86.00	537.00	6,244
10	Marshall Island	7.00	18.00	2,571

Table 1.1. Production of coconut around the world in the year 2019 (Source: International Coconut Community (ICC) Statistical Year Book 2021)

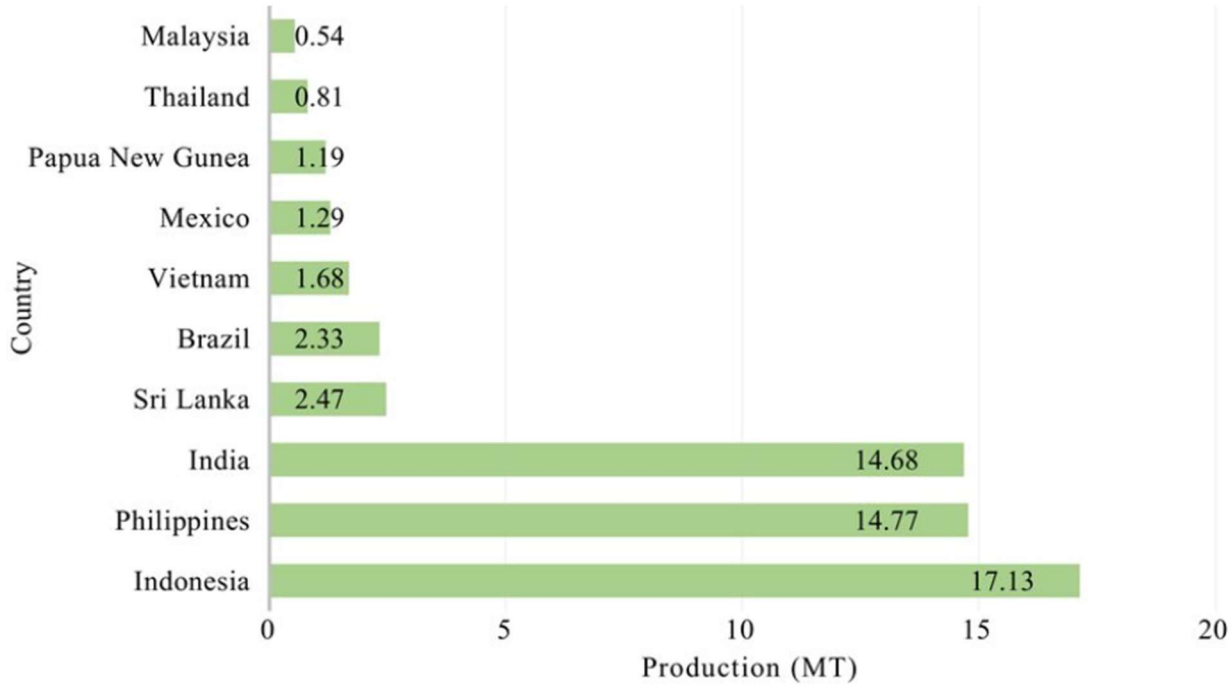

Fig. 1.1. Coconut production worldwide by leading countries (Source: FAO. 2019. FAO Statistics Database: Food and Agriculture Data. Rome:FAO)

While coconut sprouts are highly nutritious, they remain an underutilized product in Kerala. This limits the potential revenue that could be generated from the coconut sprout market. In many regions, including Kerala, this part of the coconut is not widely harvested or marketed and often goes to waste. Coconut embryos are usually found inside coconuts that have started to germinate naturally, and because they are less visible in commercial markets, many people are unaware of their value (Mu et al., 2024). In large-scale coconut farming, coconuts intended for commercial purposes, like copra (dried coconut meat) and coconut oil, are harvested before the sprouting stage. As a result, the coconut embryo, which forms only in matured and sprouted coconuts, is not a primary focus of most coconut farmers (Mu et al., 2024). Therefore, many of these coconuts that could potentially produce embryos are either discarded or remain on the ground to decompose, unless they are harvested for their sprouts.

Hence, there requires different technologies to intervene for sprouted coconuts processing, as these sprouts once removed from the shell have a very low shelf life (Valli and Gowrie, 2021). The utilization of coconut embryos in food encourages sustainable practices. By making use of more parts of the coconut, less of the crop goes to waste, enhancing the overall economic value of coconut farming.

1.3. Research gap

1. India accounts for 22.34 per cent of the world's coconut production and is one of the major players in the world's coconut trade. Currently the crop is grown in 1.91 million ha with an annual production of nearly 13000 million nuts (CDB, 2025). Due to its large production, the coconut was stored for 8-12 months, after which the sprouted coconuts were sold at a cheap price (roughly 1 rupee per nut). Farmers or sellers who do market coconut embryos often treat them as a byproduct of coconut harvesting, rather than a premium product, leading to lower profitability.

1.4. Objectives

The research objectives were framed after aligning with one of the current missions of Coconut Development Board which states "Promoting value addition in coconut processing by focusing on high value coconut products and by-products (both edible and non-edible) with health and environmentally friendly applications".

1. To determine the physico chemical properties of sprouted coconuts.
2. To assess the drying kinetics of sprouted coconuts under different dryer.
3. To identify the effect of sucrose and yeast content in wine processing.
4. To determine the quality aspect of wine.

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with the review of research work of coconut

2.1. Coconut

The development of India's coconut sector over the past two decades can be categorized into three main areas. First, there has been notable expansion in the cultivation of coconuts, extending into both traditional and non-traditional regions. Second, while the area under cultivation, production, and productivity of coconuts have increased, there has been a decline in the consumption of coconut oil in both edible and non-edible sectors. This shift highlighted the need for advanced processing technologies to ensure the sustainable growth of the industry. Third, coconut farmers have faced challenges due to price volatility and falling prices of coconuts and their derivatives, emphasizing the importance of adopting coconut-based farming systems to boost income at the farm level. High import duties on edible oils and restrictions on coconut product imports have contributed to keeping domestic prices elevated. However, the industry has faced structural limitations, preventing it from realizing its full potential due to its reliance on an oil-driven market. Recognizing the need for competitiveness, the sector is now embracing modernization, diversifying products, utilizing byproducts, and undergoing structural reforms. Consumer demand for premium coconut products is surging, invigorating domestic industries and paving the way for global competitiveness.

Following the liberalization of the Indian economy, the domestic coconut sector has struggled to match the advancements seen in leading countries like the Philippines, Indonesia, Thailand, and Sri Lanka. Nevertheless, organizations such as the Coconut Development Board, Central Plantation Crops Research Institute, and others have played a pivotal role in fostering value addition and product innovation through the introduction of suitable technologies. These efforts have led to the creation of a wide range of coconut-based products for both edible and non-edible uses.

Globalization has facilitated the integration of regional markets into a unified global marketplace, bringing international coconut products to prominence in India's food chain markets. Efforts to make Indian coconut products more accessible to international consumers have driven significant changes in domestic markets, including innovations in product development and enhanced market integration. Today, India possesses the indigenous

processing technologies necessary to produce diverse coconut-based products, including those made from the kernel, water, husk, shell, and stem. Additionally, the coconut palm's potential as a source of renewable energy is being increasingly recognized.

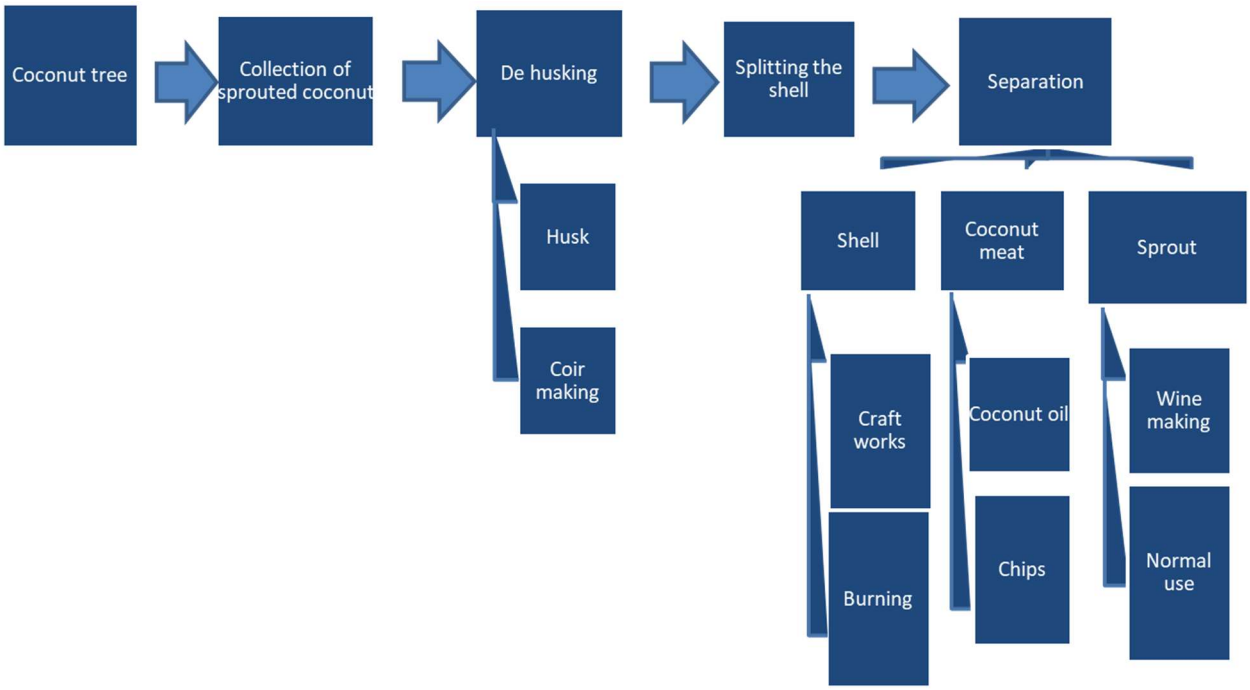

Plate 2.1. Flowchart of different uses of coconut tree

2.2. Coconut meat

The study by Ngampeerapong and Chavasit (2024) examined the nutritional and bioactive compounds in coconut meat from Thailand, Indonesia, and Vietnam. The research found that the macronutrient profiles and antioxidant activities in the meats were relatively similar across the three countries. The meats exhibited similar levels of fat, protein, and carbohydrates, suggesting that the geographical origin had little impact on these primary nutrients. The antioxidant activity was not significantly different, suggesting that the coconut species in the studied regions share common nutritional properties. However, the total phenolic content in the meat from Vietnam was 30% higher than in the samples from Thailand and Indonesia. The study also found that the phytosterol content in the meat, particularly beta-sitosterol, was high in Indonesia, suggesting potential use for bioactive compounds beneficial for cardiovascular health. The overall nutritional consistency of the coconut meat across the three countries means that trade in coconut-based products would not significantly affect consumer nutritional outcomes. The similar fatty acid profiles also suggest that coconut-derived ingredients, such as

coconut milk and coconut oil, could maintain consistent quality when sourced from these regions.

Thida Wynn's 2013 study explores the nutritional properties of coconut meat and water at different maturity stages. The findings reveal that as coconuts mature, their protein, fat, fiber, carbohydrate, and calorie contents increase, while water content decreases. This aligns with previous studies that show maturation enhances the fat and carbohydrate content of coconuts. Mature coconut meat is more energy-dense due to medium-chain triglycerides (MCTs), while immature coconuts are ideal for hydration-focused products due to their higher water content and lower calorie levels. The study also found that all coconut samples, except immature coconut water, had an acidic pH, affecting processing and shelf life. The findings suggest that mature coconut meat is valuable for energy and metabolic support, while immature coconuts are ideal for hydration-focused products. The potassium content of coconut water supports its use in rehydration and sports nutrition

The study by Nnorom et al. (2012) on the proximate composition and trace metal analysis of coconut meat and water from Southeastern Nigeria provides valuable insights into the nutritional and safety aspects of coconut consumption in the region. The study found that coconut meat contains a high percentage of crude fat, moderate levels of crude protein, and fiber, reflecting the high-energy content of coconut. Coconut water, often considered a refreshing drink, is typically low in fat and protein but rich in electrolytes like potassium and sodium. The study also found that coconut meat and water contain notable levels of essential metals like iron, zinc, and copper, which are important for human health. The low levels of cadmium, chromium, lead, and nickel in the samples analyzed by Nnorom et al. suggest that coconuts from Southeastern Nigeria are relatively safe from such contamination, making them a healthy food option. The results of the study provide valuable insights into the nutritional and health implications of coconut consumption in the region.

The study by Twishsri et al. (2024) provides valuable insights into the fatty acid and amino acid profiles of coconut endosperm from different cultivars in Thailand. The research is crucial for consumer nutrition and coconut breeding programs aiming to improve the nutritional value of coconut varieties. The study analyzed the amino acid content of two distinct coconut varieties: the young tender nut of the Aromatic Green Dwarf (Nam Hom) and the mature nut of the hybrid Nam Hom x Kathi (NHK). The findings showed significant variations in amino acid content across these varieties, with histidine and methionine being particularly significant

in the mature coconut hybrid. The study also revealed differences between the liquid and solid endosperm in terms of amino acid content, with coconut water typically low in protein and the solid endosperm being a more significant source for nutritional purposes. The fatty acid composition of coconut oil, derived from the solid endosperm, is of considerable interest due to its high saturated fat content, particularly lauric acid, known for its antimicrobial properties and potential health benefits.

The review by Yingshuang et al. (2024) discusses the potential of coconut as a plant-based food alternative, focusing on its nutritional benefits, culinary versatility, environmental sustainability, and challenges in its broader adoption. Coconut's high content of medium-chain triglycerides (MCTs) makes it popular in ketogenic and low-carb diets. It also provides essential vitamins and minerals like vitamins C and E, potassium, magnesium, and manganese, which are vital for immune support, heart health, and antioxidant protection. However, coconut's low protein content may pose a concern for those seeking to replace animal proteins.

Patil and Benjakul's (2022) study sheds light on the distinct properties of albumin and globulin fractions from coconut meat and their role in emulsion stability, both with and without proteolysis. Globulin, with its higher hydrophobicity and greater susceptibility to hydrolysis, is more effective at stabilizing emulsions compared to albumin, making it a valuable protein fraction for food and industrial applications. Furthermore, the ability of proteolysis to improve emulsion stability and increase oil recovery highlights the potential of coconut proteins in the development of functional food products and in oil extraction processes. These findings underscore the importance of protein fractionation and enzymatic modification in optimizing the functional properties of coconut proteins for a wide range of applications.

The study by Solangi and Iqbal (2011) provides valuable insights into the chemical composition of coconut meat and nut water, emphasizing the distinct nutrient profiles of these two components. While coconut water is a rich source of potassium, calcium, and magnesium, coconut meat contains higher concentrations of magnesium, sodium, and fat, making it a potent source of energy and essential minerals. The differences in the nutrient composition of the various cultivars—Tall, Dwarf, and Hybrid—underscore the potential for selecting specific varieties based on desired nutritional outcomes. This research further supports the use of coconut in the development of functional foods and beverages, especially those aimed at hydration and energy replenishment.

The study of Igbabul et al.(2014) reviewed that fermentation is a traditional biotechnological process used to enhance the nutritional and functional qualities of food products, particularly defatted coconut flour(meat). Studies have shown that fermentation can modify the proximate composition and functional properties of defatted coconut flour, making it a valuable ingredient in various food applications. The proximate composition of defatted coconut flour is influenced by the fermentation process, with significant changes in protein content, crude fat, and crude fiber. Protein content increased from 12.31% to 15.00% after 72 hours, possibly due to microbial action or the breakdown of complex carbohydrates. Crude fat content increased from 0.58% to 0.67%, possibly due to lipid metabolism by microorganisms. Crude fiber increased from 9.47% to 13.23%, possibly due to the breakdown of sugars and other fermentable materials into fiber-like substances. Moisture and ash contents decreased significantly with prolonged fermentation, possibly due to microbial consumption or mineral leaching. The carbohydrate content remained relatively stable, ranging from 67.37% to 67.41%.

2.3. Coconut water

Zhang et al. (2024) analyzed the chemical composition, nutritional value, volatile organic compounds, and biological activities of coconut water at different maturities (8, 10, and 12 months). Their study revealed that maturity influenced nutrient levels, with reducing sugar decreasing and protein and fatty acids increasing as maturity advanced. Aba et al. (2024) further explored the potential of mature coconut water as a beverage, analyzing three Philippine varieties (LAGT, CATD, and TACD). They found significant differences in pH, zinc levels, sugar composition, and antioxidant properties, highlighting its potential for sustainable beverage development. Similarly, Shayanthavi et al. (2024) studied tender coconut water from Northern Sri Lankan varieties, noting that King coconut had higher protein, soluble solids, and sugar content, while Ran thembili exhibited superior antioxidant activity and phenolic content, suggesting health benefits.

In a similar vein, Hamilton et al. (2024) studied coconut water from Edea and Bafia in Cameroon, noting variations in sugars, proteins, lipids, amino acids, and minerals. They found that higher mineral content and lower antioxidant power were present in the samples. Setiawan et al. (2024) created a freeze-dried coconut drink from young coconut water and meat, evaluating its nutrient content, sensory profile, and shelf life. The drink was found to have a rich amino acid profile and extended shelf life compared to fresh coconut drink. Reddy et al. (2024) examined high-pressure processing (HPP) on tender coconut water, demonstrating its

effectiveness in preserving nutritional composition, reducing enzyme activity, and inhibiting microbial degradation.

Bharadwaj et al. (2024) studied coconut water's metabolite and mineral profiles using 1H NMR and MPAES, finding that immature coconuts had high levels of glucose, fructose, and reducing sugars, while mature coconuts showed an increase in sucrose. Omimakinde (2024) examined Nigerian coconut varieties, revealing that Dwarf green meat had the highest ether extract and crude protein, while Dwarf yellow and red varieties had the highest carbohydrate and fiber content, emphasizing the nutritional and medicinal value of coconut products. Krishnakumar (2024) discussed the nutritional and functional properties of coconut water, noting its rich composition in sugars, minerals, vitamins, amino acids, and phytohormones, as well as its health benefits and potential applications in plant tissue culture. Mu et al. (2024) explored coconut water's applications in healthcare and biotechnology, highlighting its antioxidant, antimicrobial, anti-inflammatory, and immunomodulatory properties. They also noted its potential in plant tissue culture for enhancing callus tissue growth. Li et al. (2024) investigated the combination of high-pressure processing (HPP) and LAE-enriched polylactic acid (PLA) antimicrobial films for enhancing the microbial safety and shelf life of coconut water. Their study demonstrated that this combination reduced Staphylococcus aureus and E. coli O157:H7 CFU/mL and extended shelf life, positioning LAE-PLA films as a promising preservation technology.

Further studies, such as those by Rosniawaty et al. (2024), found that coconut water applied in various dosages significantly enhanced cocoa seedling growth, improving height, chlorophyll content, and root volume. Ningsih et al. (2024) observed that optimal properties of dried bacterial cellulose (BC) were achieved using coconut water storage time and 10% inoculum size, indicating its potential for biomaterial applications. Lastly, Qin et al. (2024) explored the biotic and abiotic factors affecting bacterial cellulose production in pre-fermented coconut water, noting that variations in microbial community structure and metabolites impacted BC production, providing valuable insights for industrial production.

Coulibaly et al. (2023) evaluated the nutritional, biochemical, and microbiological properties of coconut water in Abidjan, Côte d'Ivoire. They found that while coconut water is popular for its perceived health benefits, its microbiological quality was unacceptable, indicating potential health risks. Similarly, Lemos, Aniceto, and Teodoro (2023) explored non-thermal processing methods like ultrapressure, which help preserve the shelf life of coconut water while

maintaining its nutritional quality, though they emphasized the need for further research on its health benefits. Adeoye et al. (2023) compared the antioxidant activity and total antioxidant capacity of coconut oil and coconut water, finding that although there were no significant differences in DPPH scavenging activity, coconut water had higher levels of essential metals, suggesting potential benefits in addressing mineral deficiencies.

In hydration research, O'Brien et al. (2023) found no significant differences between coconut water and sports drinks when used by cyclists for endurance hydration, indicating that coconut water could be a viable alternative. Meanwhile, Aniceto et al. (2023) developed fruit beverages using coconut water as a base, discovering that a blend with guava showed superior antioxidant capacity and good sensory acceptance, making it a promising product for the beverage market. On the fermentation side, Limbad et al. (2023) examined coconut water kefir, revealing significant carboxylic acid production and a decline in amino acid profiles, while Aziz et al. (2023) found that fermentation with kefir grains improved the palatability of mature coconut water, with the three-day fermented version receiving high acceptance scores.

Pérez et al. (2023) investigated the impact of thermal processing on a coconut water and rice flour beverage, showing that sterilization and pasteurization increased acidity but decreased antioxidant activity, yet the mixture remained a viable non-dairy substrate. Detudom et al. (2023) focused on the storage of coconut water, noting that microbial growth, particularly from LAB species like *Weissella cibaria* and *Leuconostoc spp.*, was accelerated at ambient temperatures, underlining the importance of controlling storage conditions. Peixoto et al. (2023) studied trace elements in natural and processed coconut water, finding significant differences in essential and potentially toxic elements, and highlighting the need for monitoring these elements for safe consumption.

Chutimanukul et al. (2023) found that coconut water application significantly improved the growth and bioactive compound production of the medicinal mushroom *Hericium erinaceus*. Wulansari et al. (2023) discovered that the novel enzyme IfDPEase from *Iocasia fonsfrigidae* could improve coconut water quality by converting D-fructose into low-calorie sugar. Yudianto et al. (2023) explored ozonation as a non-thermal alternative for achieving commercial sterility in coconut water, showing its effectiveness in inactivating bacterial spores and enzymes. Lastly, Raj et al. (2023) compared the antioxidant and therapeutic properties of fresh coconut water and naturally fermented coconut water, finding superior inhibitory effects in the fresh version. Basak et al. (2023) demonstrated that pulsed light treatment for pasteurizing tender coconut

water could effectively reduce microbial resistance while preserving phenolics and ascorbic acid, offering a promising non-thermal pasteurization method.

Nadila et al. (2022) conducted a systematic review on the health potential of young coconut water, emphasizing its nutrient-rich composition, including vitamins, minerals, amino acids, and sugars, which contribute to various health benefits, positioning it as a valuable dietary supplement. Rethinam and Krishnakumar (2022) further explored the composition and properties of coconut water, identifying essential constituents like amino acids, antimicrobial peptides, aromatic compounds, electrolytes, enzymes, phytohormones, polyphenols, sugars, and vitamins, all of which contribute to its health benefits. They also noted that advancements in analytical techniques could further enhance our understanding of coconut water's potential health benefits.

Naik et al. (2022) highlighted the rising global demand for coconut water due to its low-calorie content and nutritional benefits. However, traditional processing methods often lead to nutrient loss, making recent advancements in preservation techniques critical for maintaining its nutritional value. Xu et al. (2022) investigated the production of high-value vinegar from mature coconut water through liquid-state fermentation, revealing that the aged vinegar had pleasant aromas and improved palatability, enhancing its nutritional and flavor potential. Asaad, Jailani, and Ab Mutalib (2022) studied the properties of coconut water and flesh, noting that tall coconuts had higher water volume, pH, and phenolic content, while dwarf and hybrid coconuts were preferred for their taste.

Phonphoem et al. (2022) found that Makapuno coconuts, a natural mutant variety, have high nutritional value, phytochemical composition, and antioxidant properties, making them a promising food ingredient. Rajashri et al. (2022) focused on non-thermal processing techniques for preserving tender coconut water, demonstrating their effectiveness in maintaining its fresh-like quality and extending its shelf life. In agricultural studies, Salman and Abdulrasool (2022) found that ozone enrichment and foliar spraying of coconut water and moringa extract significantly improved broccoli plant growth and yield, with ozone enrichment being particularly effective in enhancing plant weight and yield. Similarly, Ansar and Paiman (2022) discovered that coconut water at a 40% concentration improved shallot growth and yield in Central Sulawesi, Indonesia, while Moringa leaf extract showed positive effects, albeit at higher concentrations.

Finally, Windarsih et al. (2022) synthesized gold-modified bacterial cellulose nanoparticles from coconut water waste, demonstrating significant antibacterial activity against various bacteria, with the highest effect observed at a 1:100 ratio, highlighting its potential as a novel antimicrobial material.

Tuyekar et al. (2021) discuss the health benefits of coconut water, emphasizing its nutritional content and medicinal properties. Kumar et al. (2021) further examined the nutritional and metabolomic characteristics of the Chowghat Orange Dwarf and Malayan Yellow Dwarf coconut varieties, identifying key metabolites that can help optimize coconut water's nutritional profile. Alchoubassi et al. (2021) studied essential nutrient trace elements in coconut water, revealing that these elements form low-molecular-weight stable complexes, with concentrations varying by coconut origin and maturity. Dorathy et al. (2021) analyzed the mineral composition, phytochemicals, and antimicrobial activity of coconut water, suggesting its potential use in oral care systems.

Oluwarotimi et al. (2021) highlighted the antioxidant and therapeutic properties of coconut water, particularly in treating amnesia in *Drosophila melanogaster* models. Muthia et al. (2021) found that freeze-dried coconut water from mature hybrid coconuts could serve as a high-quality alternative to fresh coconut drinks, maintaining similar sensory and physicochemical properties. Costa et al. (2021) fortified coconut water with microencapsulated grape pomace extract to create an electrolyte beverage, showing that the fortified coconut water reduced pathogen growth and supported beneficial probiotic bacteria. Widiwurjani et al. (2021) demonstrated that coconut water waste could enhance the growth and nutritional content of Kailan microgreens, with optimal conditions involving a 25% concentration and three daily watering frequencies.

Prithviraj et al. (2021) explored non-thermal processing techniques for preserving tender coconut water, highlighting their advantages over traditional thermal methods, including enzyme inactivation and reduced microbial load. Raut et al. (2021) used coconut water as an eco-friendly material for developing a carbonaceous electrode for bifunctional water splitting applications, showcasing its potential in sustainable energy. Estévez (2021) explored coconut water's dual roles as a biostimulant and anti-cancer agent, noting its high mineral content and bioactive cytokinins, which promote plant growth and may have medical applications. Zhang et al. (2021) found that coconut water can significantly reduce diabetic cataract severity in rats

through its antioxidant properties, suggesting its potential as a functional food for preventing diabetic cataracts.

Pinto et al. (2021) found that microwave processing of acidified green coconut water is a promising alternative to traditional thermal methods, with temperature influencing the results. Wu et al. (2021) discovered that ultrasonic treatment of coconuts increased sweetness and shelf life but inhibited sugar metabolism enzymes, thus affecting sugar content. Finally, Trindade et al. (2021) optimized a DLLME method to determine copper and manganese levels in coconut water using flame atomic absorption spectrometry, achieving high analytical precision and recovery rates.

Burns et al. (2020) conducted a critical review on the authenticity and potability of coconut water, focusing on its maturity at harvest, natural composition, processing effects, and potential adulterations. The review emphasized analytical methods for verifying authenticity and ensuring safety, offering guidance for food analysts to detect adulterations and maintain product quality. Cunha et al. (2020) explored the effects of thermal processing on coconut water, finding that it increases long-chain saturated fatty acids, decreases sugars, and enhances the formation of oligomeric procyanidins, which contribute to the characteristic pink color of coconut water, providing valuable insights into product quality. Schiassi et al. (2020) optimized the sensory and nutritional quality of mixed berry juice with coconut water by combining strawberries, blackberries, and raspberries, resulting in superior properties.

Segura-Badilla et al. (2020) developed a symbiotic functional drink using coconut water, fermented with *Lactobacillus rhamnosus* SP1 and inulin to provide soluble fiber, achieving optimal concentrations and sensory acceptance. Igbokwe et al. (2020) demonstrated that coconut water, rich in nutrients, can be used as an infusion fluid for health benefits, although its composition varies by region. Praia et al. (2020) developed a low-cost, lactose-free probiotic drink using coconut water fermented by *Lactobacillus casei* Shirota, providing health benefits and offering a non-dairy beverage alternative for lactose-intolerant consumers. Madihalli, Sudhakar, and Doble (2020) found that coconut water can be used as a carbon source for producing MEL-A, a biosurfactant, suggesting it as an efficient substrate for biosurfactant production and pharmaceutical applications due to its superior properties and emulsion stability.

Biswas et al. (2020) showed that using green-synthesized silver nanoparticles (AgNPs) in coconut water can extend its shelf life and prevent microbial degradation, enhancing its

functional food potential. Limbad et al. (2020) found that a coconut water kefir starter culture, containing *Lactobacillus plantarum*, significantly improved the sensory attributes and nutritional value of sourdough bread. Zulaikhah (2020) highlighted the antioxidant properties of tender coconut water (TCW), emphasizing its bioactive compounds, including L-arginine, methionine, cytokines, selenium, and vitamin C, which contribute to its significant nutritional and health benefits. Porto et al. (2020) explored ozone and atmospheric cold plasma processing to preserve the quality of green coconut water without altering its pH, solids, acidity, or color.

Super Nova et al. (2020) found that TCW can reduce glucose levels and increase plasma insulin levels in pregnant diabetic rats, suggesting its potential role in diabetes treatment. Ng (2020) showed that waste coconut water can enhance stem elongation in *Hylocereus polyrhizus* micropropagation, offering a cost-effective alternative to synthetic growth regulators.

Ekasari and Widyarti (2019) compared natural coconut water (NCW) and packaged coconut water (PCW), finding that PCW had higher absorbance and turbidity, possibly due to packaging ingredients. Heating did not significantly affect NCW's properties, and both types had similar pH levels and conductivity values. Shigematsu et al. (2020) discovered that adding coconut water to a sodium alginate-based edible coating improved the viability of *Lactobacillus acidophilus* LA3 and maintained the sensory quality of minimally processed carrots, with panelists showing higher acceptance and purchase intention throughout the storage period. Mohamad et al. (2019) found that coconut water vinegar significantly reduced 4T1 breast cancer cell viability, induced apoptosis, and inhibited wound healing, with in vivo studies showing delayed tumor progression and enhanced immune responses in mice.

Bhullar et al. (2019) demonstrated that UV-C irradiation effectively inactivated microorganisms in coconut water, making it a promising technique for treating other liquid foods. Hosseini et al. (2020) identified significant fluoride content in coconut water, indicating that daily intake could contribute 15% to 30% of the recommended fluoride intake. Eswaran et al. (2019) studied the effects of flash pasteurization (FP) and radio frequency (RF) treatments on mature coconut water, finding FP to be more effective in inactivating enzymes and microbial flora, while RF preserved the water's physicochemical properties. Sumonsiri (2019) found that nisin significantly inhibited bacterial growth in micro-filtered coconut water, resulting in lower microbial counts and higher overall acceptance scores.

Uddin et al. (2019) found that coconut water effectively managed diabetes in rabbits, reducing weight loss, frequent urination, and elevated blood glucose levels, suggesting its potential as a

functional food or nutraceutical. Paixão et al. (2019) found cadmium and lead in commercial coconut water and milk samples, exceeding legal limits set by ANVISA, highlighting potential health risks in coconut-based products. Mahnot et al. (2019) demonstrated that non-thermal microfiltration, combined with citric acid, ascorbic acid, and orange honey, effectively enhanced the shelf life of tender coconut water, reducing sugars while maintaining stability. Rodsamran and Sothornvit (2019) developed bioactive pectin films using lime peel residues and coconut water, which enhanced water barrier properties, antioxidant activity, and effectively retarded soybean oil oxidation.

Lucas et al. (2019) used powdered coconut water in a sol-gel method to create niobium pentoxide powders, which exhibited stable dielectric properties independent of temperature and frequency, indicating their potential for use in electronic device applications.

Reddy et al. (2018) highlighted the health benefits of tender coconut water (TCW), noting its high levels of free amino acids and vitamin C, which help prevent heart diseases and lipid peroxidation. Regular consumption of TCW improves antioxidant enzyme activities and reduces lipid peroxidation, although it has not gained widespread acceptance as an intravenous fluid. Halim et al. (2018) found that mature coconut water, particularly from the MATAG variety, exhibited superior properties, making it suitable for energy drinks. Chinasa (2018) emphasized coconut water's rich lauric acid, antifungal, antibacterial, antiviral properties, and low-calorie content. Ogunmefun et al. (2018) developed a blend of coconut and pineapple juices, showing high alkaloid content and antimicrobial properties, making it a potential functional beverage.

Giri et al. (2018) found that fermented coconut water with *Lactobacillus casei* L4 enhanced nutritional and probiotic properties, increasing antioxidant and antibacterial properties. Anselme et al. (2018) assessed the physicochemical and microbiological properties of coconut water and sugar extraction from five ecotypes in Côte d'Ivoire, showing that hybrid coconuts required fewer nuts for water production. Rodsamran and Sothornvit (2018) discovered that coconut by-products like coconut milk cake and mature coconut water could be used to create bioactive protein films, improving antioxidant properties and mechanical strength. Gunathunga et al. (2018) found that heat and UV-C treatments effectively preserve the physiochemical, microbiological, and sensory properties of tender coconut water, ensuring safety and extended shelf life.

Donsingha and Assatarakul (2018) found that UV radiation significantly improved the shelf life of coconut water, inactivating microorganisms and enhancing quality and safety compared to pasteurization. Bhullar et al. (2018) confirmed that UV-C irradiation effectively reduces microbial load in coconut water without forming harmful compounds, presenting it as a safe and promising food preservation technology. Seow et al. (2017) compared fresh and freeze-concentrated coconut water, finding that the freeze-concentrated version had higher nutritional content and consumer acceptability, making it a better rehydration option. Wynn (2017) noted that the nutritional profile of coconut meat and water changes as the coconut matures, with increased protein, fat, fiber, and calorie content, but decreased water content.

Marapana et al. (2017) developed a nutrient-fortified isotonic beverage from king coconut water, suitable for athletes, with microbiological stability. Kantachote et al. (2017) found that fermented mature coconut water with *Lactobacillus plantarum* DW12, a potential probiotic, offers health benefits and antioxidants. Hidalgo (2017) studied pasteurized coconut water in the Philippine beverage industry, finding it well-received as a functional health drink, offering a natural and health-oriented appeal. Thomas et al. (2017) found that tender coconut water effectively lowers triglycerides, total cholesterol, and low-density lipoprotein cholesterol levels in male Wistar rats, suggesting its potential in managing dyslipidemia.

Sanganamoni et al. (2017) found that UV-C treatment significantly affected the nutritional properties and enzymes of tender coconut water, with UV-C treatment being superior in retaining these attributes compared to thermal processing. Sucupira et al. (2017) observed that sterilization and the addition of sulphites minimally affected coconut water's chemical composition, with higher temperatures preventing pinking and preserving organic compounds. Gordon and Jackson (2017) proposed improvements in coconut water harvesting, bottling, and good manufacturing practices to extend shelf life and ensure product safety. Rojas et al. (2017) found that ultrasound technology effectively inactivated and sensitized peroxidase in green coconut water, improving thermal processing efficiency while preserving nutritional and sensory qualities.

Nambiar et al. (2017) studied microencapsulation of tender coconut water and found that higher MG concentration, lower MD concentration, and lower inlet temperature improved encapsulation efficiency and antioxidant activity. Ribeiro et al. (2017) found that thermosonication, combining ultrasound with heat, effectively reduced enzymatic activity in coconut water, offering a promising alternative to traditional thermal treatments.

Adubofuor et al. (2016) examined the effects of pasteurization on coconut water from Malayan Green and Malayan Yellow varieties, finding that pasteurization reduced microbial load but decreased sensory and nutritional quality, with Malayan Green being more stable. Geetha et al. (2016) studied coconut testa and tender coconut water concentrates, revealing strong antioxidant activities and potential for treating stress-induced ailments. Mahayothee et al. (2016) found increased phenolic content and antioxidant activity in coconut water and meat at maturity stages, with fat content increasing, providing insights for specific uses. Rao and Najam (2016) compared young and mature coconut water and found that young coconut water significantly inhibited inflammation, while mature coconut water showed moderate effects.

Bandalan and Galvez (2016) optimized a coconut water beverage with *Lactobacillus acidophilus*, enhancing its nutritional value and ensuring stability for 15 days. Bridgemohan and Bridgemohan (2016) developed freeze-dried coconut water as an oral rehydration salt substitute, offering a more accessible alternative for rural areas. Choudhary et al. (2016) explored non-thermal processing techniques for coconut water, highlighting high-pressure carbon dioxide technologies as a promising preservation method. Aziz et al. (2016) developed Azest, a functional sports drink from matured coconut water vinegar, aiding in muscle glycogen repletion post-exercise, with higher sweetness levels compared to commercial sports drinks.

Umesha and Narayanaswamy (2016) studied the growth-promoting substances in desiccated coconut mill coconut water, revealing that concentrated coconut milk had the highest effects on macronutrient and micronutrient concentrations. Ramos and Galvez (2016) optimized a coconut water and sweetpotato blended beverage, determining the optimal formulation with 18% sugar, 12% calamansi, and 20% sweetpotato. Purbia and Paria (2016) developed a fluorescent sensor for thiamine detection using luminescent carbon dots from coconut water, which showed low detection limits and minimal interference. Karunarathna and Harris (2016) found that coconut water significantly improved cutting establishment in *Ixora coccinea* in Sri Lanka, enhancing root length and plant height.

Trinh et al. (2016) studied coconut water vinegar production through a two-step fermentation process, finding that sugar concentration and yeast amounts influenced fermentation efficiency. Anith et al. (2016) examined the population dynamics of a coconut water-based formulation of *Pseudomonas fluorescens AMB-8* for plant growth promotion, showing that coconut water amended with 2% PVP and 2% glycerol maintained a higher bacterial population during storage.

Appaiah et al. (2015) evaluated the physico-chemical characteristics, phytonutrient content, and stability of coconut water and other commercial coconut products at different maturity stages, revealing their potential for functional food preparation. Cappelletti et al. (2015) found that High Pressure Carbon Dioxide (HPCD) treatment effectively preserved coconut water's nutritional and sensory qualities while reducing microbial growth. Prado et al. (2015) created a fermented coconut water beverage using *Lactobacillus plantarum*, offering a non-dairy alternative for vegans and lactose-intolerant individuals. Lazim et al. (2015) analyzed cytokinin content in coconut water from different varieties, revealing that Malayan Green Dwarf had the highest content of trans-zeatin riboside.

Limbad et al. (2015) explored the health benefits of coconut water, including its medicinal and biocatalytic properties, particularly in fermented beverages. Sinaga et al. (2015) found that young coconut water and meat were richer in protein and non-protein nitrogen than mature coconuts, indicating their higher nutritional value. Costa et al. (2015) studied the physicochemical degradation of coconut water, revealing changes in pH and chemical profile, suggesting its potential for consumption. Leishman (2015) compared coconut water with sports drinks and plain water, finding no significant differences in rehydration or performance benefits.

Augusto et al. (2015) found that UV radiation effectively inactivated peroxidase and polyphenol oxidase enzymes in coconut water, making it an efficient processing technique without undesirable changes. Jacob et al. (2015) found that coconut water gelatin supported the mycelial growth of three *Pleurotus* species, with *P. citrinopileatus* showing the fastest growth. Winarto and Teixeira da Silva (2015) found that adding coconut water and fertilizer to Murashige and Skoog medium improved orchid growth and germination. Franco et al. (2015) studied the dielectric properties of green coconut water during microwave processing, revealing significant ionic conduction and reduced loss factors. Gayathry (2015) developed Nata de Coco using mature coconut water and *Gluconacetobacter xylinum*, yielding high fiber content with excellent water-holding capacity.

Shubhashree et al. (2014) reviewed coconut water's therapeutic and nutritional benefits, emphasizing its potential in the functional food, nutraceutical, and pharmaceutical markets due to rising public awareness. Laitano (2014) found that coconut water enhanced fluid retention, exercise capacity, and gastrointestinal distress in heat, compared to plain water and flavored beverages, while reducing urine output. Agbafor et al. (2014) showed that coconut water, rich

in antioxidants, can reduce cholesterol, triglycerides, and LDL levels in rats, potentially aiding in cardiovascular disorder management. Manna et al. (2014) demonstrated that coconut water concentrate and shikimic acid significantly reduce oxidative stress in murine hepatocytes by activating apoptotic molecules and enhancing Nrf2-mediated antioxidant responses.

Tan et al. (2014) examined the thermal inactivation kinetics of polyphenol oxidase and peroxidase in coconut water from immature, mature, and overly mature coconuts. Chauhan et al. (2014) developed a beverage by blending coconut water with lemon juice, optimizing the composition for a shelf life of 6 months. Cappelletti et al. (2014) combined supercritical carbon dioxide and high-power ultrasound to reduce microbial flora and Salmonella in coconut water pasteurization, ensuring a stable shelf life. Vishakh et al. (2014) found that tender coconut water (TCW) and synthetic trans-zeatin possess significant antioxidant properties. Kathiravan et al. (2014) optimized a coconut water and nannari extract beverage, with pulsed electric field treatment preserving its nutritional and sensory attributes.

Johnkennedy et al. (2014) found that coconut water consumption significantly increased testosterone, FSH, and LH levels in female rats, potentially enhancing reproductive health. Elumalai et al. (2014) used coconut water for green synthesis of silver nanoparticles, offering an eco-friendly alternative to traditional methods. Othaman et al. (2014) explored vinegar production from mature coconut water, finding that sucrose fermentation with *Acetobacter aceti* improved efficiency. Laux et al. (2014) utilized ultrasonic waves to measure the longitudinal viscosity of coconut water, showing its potential for real-time, in-line measurements during production.

Ibe et al. (2013) analyzed Nigerian coconut water, revealing it to be rich in electrolytes, particularly potassium, with a pH of 5.4, indicating potential clinical applications. Santos et al. (2013) found that the green dwarf variety of coconut water had the strongest antioxidant activity. Chidambaram et al. (2013) found that tender coconut water from Tamil Nadu had high electrical conductivity and potassium chloride content. Lee et al. (2013) fermented coconut water with *Lactobacillus acidophilus* and *Lactobacillus casei* to create a functional beverage offering electrolytes and probiotics.

de Farias et al. (2013) found that modified coconut water (3% sodium) significantly reduced liver function markers and renal damage in rats with hemorrhagic shock, suggesting its superior benefits over fresh blood and saline. Assa et al. (2013) noted that sensory and sugar characteristics of coconut water vary by cultivar and maturity stage, with sweeter water

preferred. Lukas (2013) found that High Pressure Processing (HPP) effectively reduced foodborne pathogens while maintaining the water's organoleptic and nutritive properties. Sekar et al. (2013) used tender coconut water as a growth medium for recombinant protein production in *Escherichia coli* and *Pichia pastoris*, demonstrating its cost-effectiveness and sustainability.

Debien et al. (2013) evaluated ultrafiltration (UF) membrane performance for coconut water, with PES membranes showing the best permeate flux. Deme et al. (2013) developed a method for detecting organophosphorus pesticide residues in coconut water using solid-phase extraction and LC-ESI-MS/MS, finding high accuracy in malathion detection. Zhou et al. (2013) found that homemade coconut water beverages stored at 4°C maintained stable components, low bacterial colony count, and minimal nutrient loss, indicating potential for market use. Preetha et al. (2013) found that mature coconut water reduced blood glucose, improved insulin levels, and promoted pancreatic regeneration in diabetic rats. John et al. (2013) explored using waste paper hydrolysate and coconut water as carbon sources for producing bacterial cellulose and cellulase enzymes.

Prades et al. (2012) studied coconut water's uses, composition, and properties, highlighting its hydrating, natural sports, and medicinal benefits. They emphasized the need for further research to fully explore its potential. Medeiros and Vanessa (2012) discussed coconut water's therapeutic use, noting its high antioxidant, potassium, calcium, and carbohydrate content, and its benefits for hypertension, rehydration, exercise performance, and mild diarrhea, though caution was advised for severe cases or impaired renal function. Adolf et al. (2012) found that fresh coconut water supports bacterial growth, posing health risks, and recommended consuming it directly from the coconut to limit contamination. Kalman et al. (2012) found no significant differences in fluid retention and hydration between coconut water, concentrate, and sport drinks.

Gunathilake and Rathnayake (2012) determined optimal pasteurization conditions for King coconut water, enabling safe storage at 4°C for up to eight weeks. Martins and Waldschutz (2012) found coconut water improved endurance power in aging male joggers during physical activity compared to carbohydrate-electrolyte beverages. Preetha et al. (2012) found mature coconut water reduced blood glucose and oxidative stress in diabetic rats, increasing antioxidant enzyme activity and reducing lipid peroxidation, making it a promising remedy for diabetes. Purkayastha et al. (2012) showed that microfiltration with L-ascorbic acid improved the quality of coconut water stored at 4°C for 28 days. Michael (2012) found that coconut water

improved callus initiation, shoot proliferation, and plant regeneration in sweetpotato cultivars in Papua New Guinea.

Prades et al. (2012) analyzed the volatile profile of coconut water, finding significant differences in ketones, aldehydes, and lactone content across varieties. Santos et al. (2012) developed an effective method to detect pesticide residues in lyophilized coconut water. Berger et al. (2012) found coconut water to be an effective medium for producing chitin and chitosan, offering a low-cost alternative to synthetic media. Aysha et al. (2012) demonstrated that coconut water enriched plant growth-promoting rhizobacteria, enhancing tomato plant growth and seed colonization.

Awua et al. (2011) studied the physicochemical changes in coconut water after sterilization and storage, revealing significant changes in pH, turbidity, and dry matter content. Prathapan and Rajamohan (2011) found that tender coconut water (TCW) showed superior antioxidant and antithrombotic effects in a rat model of myocardial infarction, suggesting its potential in managing coronary vascular diseases. Boonnumma et al. (2011) developed freeze-dried coconut water powder to preserve its nutritional benefits and flavor, recommending further studies to incorporate tender coconut meat. Konan et al. (2011) studied coconut water biochemical characteristics during germination, finding specific cultivars suitable for vinegar production. Jayakody et al. (2011) highlighted that evaporation negatively impacts coconut water sugar content, with increased pressure and concentration causing sugar degradation.

Naozuka et al. (2011) studied the chemical composition of unprocessed and processed coconut waters, finding variations in metal and anion levels. Medhe et al. (2011) used HPTLC to identify and quantify amino acids in coconut water, revealing its nutritional value. Gomes et al. (2011) explored the potential of Eu3+-doped Y2O3 nanoparticles using a coconut water-assisted sol-gel method. Ajeigbe et al. (2011) found that coconut water significantly reduced nociception and inflammation in rats, suggesting its potential as an analgesic and anti-inflammatory agent. Gunathilake et al. (2011) developed a cost-effective method for making coconut water vinegar using a vinegar generator, proving efficient in acetification.

Nagamaniammai et al. (2010) optimized the quality of membrane-concentrated tender coconut water using reverse osmosis, enhancing shelf life and nutritional attributes. Asante-Donyinah (2010) developed a sports drink combining coconut water and pineapple juice, achieving a 12-month shelf life. Bhagya et al. (2010) found that TCW improved electrolyte balance and normalized kidney function in hypertensive rats. Silva et al. (2010) demonstrated that

powdered coconut water enhanced canine oocyte maturation in vitro. Sujarit et al. (2010) found that coconut water significantly enhanced astaxanthin production in Phaffia rhodozyma, reducing energy costs. Mukarlina et al. (2010) found that coconut water influenced the growth of *Paraphalaeonopsis serpentilingua*, suggesting its potential as a growth regulator.

Jayanti et al. (2010) optimized coconut water clarification using ultrafiltration, improving productivity and cleaning cycles. Seesuriyachan et al. (2010) used coconut water and sugarcane juice to produce high concentrations of EPS in solid-state fermentation by *Lactobacillus confusus*. Al-Khayri (2010) found that coconut water supplementation enhanced callus growth and embryo formation in date palms. Afroz et al. (2010) demonstrated that coconut water significantly improved tomato regeneration efficiency, with a high rate of 95.75%. Leal Junior (2010) compared different preservation processes on coconut water, highlighting variations in soluble solids, pH, and phenolic content. Mohammed and Ali (2010) found that coconut water enhanced callus formation in guar plant tissue culture, reducing induction time. Lima et al. (2010) showed that ACP-based medium preserved canine preantral ovarian follicles, offering potential applications in veterinary science.

2.4. Nutritional composition of coconut oil and its applications

Adeoye et al. (2023) conducted a comparative analysis of phytochemicals and nutritionally essential metals in coconut oil and coconut water fractions. Their study revealed that coconut oil is abundant in medium-chain triglycerides (MCTs), particularly lauric acid. Lauric acid, comprising about 49% of the oil, is known for its strong antimicrobial properties due to its ability to disrupt lipid membranes of bacteria and viruses. The study also found that coconut oil has high antioxidant capacity as indicated by its DPPH scavenging activity, which is comparable to some synthetic antioxidants. However, the content of essential metals like zinc and selenium was lower in coconut oil compared to coconut water, which could limit its use as a dietary supplement in regions with potential metal deficiencies. This research underscores the importance of considering the dual use of coconut oil not only as a food product but also in therapeutic applications due to its lipid profile and antioxidant properties.

Omimakinde (2024) analyzed various Nigerian coconut varieties to determine the best source of coconut oil with superior nutritional properties. The study found that Dwarf Green coconut oil had the highest concentration of lauric acid (49%) and medium-chain fatty acids. This high concentration of MCTs is crucial for its role in energy provision and weight management. The study also noted variations in lipid profiles among different varieties, emphasizing the need for

region-specific applications. For example, the Dwarf Green variety could be particularly useful in regions where high antimicrobial activity is required. This finding is significant for understanding the nutritional diversity in coconut oil production, which can inform consumer choices and help in the development of targeted health products.

Reddy et al. (2024) studied the physicochemical characteristics of virgin coconut oil (VCO) and refined coconut oil (RCO). Their research showed that VCO, obtained through cold-pressing, retained significantly higher levels of antioxidants and polyphenols compared to RCO, which is extracted from dried coconut meat (copra) using heat-based methods. The retention of these compounds in VCO is attributed to the minimal processing involved, which prevents the oxidation of polyphenols and other heat-sensitive compounds. This study is crucial as it highlights the health benefits of consuming VCO over RCO, especially for its potential in reducing oxidative stress and inflammation. The superior oxidative stability of VCO makes it ideal for use in both dietary applications and the cosmetic industry, where it is used for its emollient and protective properties on the skin.

Krishnakumar (2024) explored the functional properties of MCTs in coconut oil, particularly focusing on their impact on brain health. MCTs, such as those found in coconut oil, are rapidly metabolized into ketones, which provide an alternative energy source for the brain when glucose levels are low. This conversion is critical for individuals with metabolic disorders like Alzheimer's disease, where the brain's ability to utilize glucose is compromised. The research showed that coconut oil could potentially improve cognitive function and slow the progression of neurodegenerative diseases due to its rich MCT content. This finding is significant for developing functional foods and supplements aimed at managing cognitive decline and providing therapeutic benefits in neurological health.

Mu et al. (2024) reviewed the application of coconut oil in healthcare and biotechnology. The study highlighted its wide use in the cosmetic industry for skincare products due to its moisturizing, emollient, and anti-inflammatory properties. Coconut oil is also used in pharmaceuticals as a carrier oil for drug delivery systems because of its ability to improve drug solubility and skin absorption. The review pointed out that the antimicrobial properties of coconut oil, particularly against gram-positive bacteria, make it effective in treating skin infections and promoting wound healing. This versatility makes coconut oil a valuable ingredient in both traditional and modern medicine, offering potential benefits beyond just nutrition.

Nadila et al. (2022) conducted a systematic review on the processing methods for coconut oil, with a focus on the preservation of its bioactive compounds. They found that cold-pressed methods are the most effective in retaining natural antioxidants, vitamins, and beneficial fatty acids like lauric acid and capric acid. The study discussed the advantages of cold-pressing, such as reducing heat exposure and chemical solvents, which can degrade the oil's nutritional value. This review highlighted the growing demand for natural and minimally processed coconut oil in markets where consumers seek high-quality health products. It also stressed the importance of adopting sustainable processing techniques to minimize environmental impact while preserving the nutritional integrity of the oil.

Peixoto et al. (2023) analyzed trace elements in natural and processed coconut oils, finding that natural coconut oil retains higher levels of essential elements like zinc and selenium. However, processed oils, especially those subjected to high temperatures or chemical treatments, contained lower levels of these metals, raising concerns about the nutritional quality and safety of these products. The study emphasized the need for rigorous quality control during the production of coconut oil to ensure that harmful trace elements do not exceed safe consumption levels. This research is crucial for regulatory bodies to establish guidelines for acceptable limits of metal content in processed coconut oil, thus safeguarding consumer health.

Cunha et al. (2020) studied the impact of thermal processing on the nutritional quality of coconut oil. The findings showed that high-temperature refining led to an increase in long-chain saturated fatty acids, such as palmitic and stearic acids, while reducing the content of polyphenols. The degradation of antioxidants in the oil under high heat conditions compromises its health benefits, particularly its ability to reduce oxidative stress. This study highlighted the necessity for low-heat extraction methods, such as cold-pressing and microfiltration, to preserve the beneficial compounds in coconut oil. It suggested that future processing techniques should focus on maintaining the oil's nutrient profile to maximize its functional properties.

Bridgemohan and Bridgemohan (2016) investigated the use of freeze-drying for preserving coconut oil. The process was found to effectively maintain the oil's sensory qualities and extend its shelf life, making it suitable for long-term storage and use in nutraceutical products. Freeze-drying helps prevent oxidation, retaining the oil's natural flavor, color, and nutritional properties. This method is particularly beneficial for developing functional food products where the preservation of these qualities is crucial. The research also highlighted the potential

for using freeze-drying in the development of coconut oil-based dietary supplements, ensuring product stability and efficacy over time.

Mahayothee et al. (2016) examined the impact of coconut maturity on the composition of coconut oil. The study found that mature coconuts produce oil with higher concentrations of lauric acid (49%) and antioxidants compared to immature coconuts. These components contribute to the oil's antimicrobial and antioxidant properties, making it more effective for dietary and cosmetic applications. The research also provided insights into the best coconut maturity stages for optimal oil quality, which is crucial for producers aiming to meet market demands for high-quality, functional coconut oil.

Hamilton et al. (2024) evaluated coconut oil derived from different coconut varieties, revealing significant differences in lauric acid content, vitamin E levels, and oxidative stability. The study showed that coconut oil from certain varieties has superior antimicrobial and antioxidant properties, making it more suitable for therapeutic uses. This research underscores the importance of selecting the right coconut variety for specific applications, whether it be in food products, skincare, or pharmaceuticals. The study also pointed out the potential for breeding and selecting varieties with enhanced nutritional profiles to meet the growing demand for high-quality coconut oil.

Burns et al. (2020) critically reviewed the authenticity and quality of coconut oil, focusing on its chemical composition and processing techniques. The review highlighted the challenges of ensuring product purity, especially in the context of adulteration and fraudulent practices. It emphasized the need for analytical methods, such as gas chromatography and mass spectrometry, to verify the authenticity of coconut oil in the market. The study also discussed the regulatory implications for producers and consumers, recommending stricter controls to prevent the sale of adulterated products. This critical review is essential for understanding the complexities of the coconut oil market and for implementing measures to protect consumer health.

Choudhary et al. (2016) investigated non-thermal processing methods, such as high-pressure carbon dioxide extraction, to preserve the oil's nutritional and sensory qualities. The study found that these methods retained the oil's beneficial fatty acids and antioxidants, making them preferable for high-value applications in the cosmetic and nutraceutical industries. The non-thermal techniques also demonstrated potential for large-scale industrial use, providing a safer alternative to conventional thermal methods. The findings suggest that adopting such

technologies can help produce high-quality coconut oil while reducing energy consumption and environmental impact.

Muthia et al. (2021) analyzed the effects of coconut variety and maturity stage on the physicochemical properties of coconut oil. The study revealed that hybrid coconuts, which are a mix of different varieties, yielded oil with balanced medium-chain fatty acids and polyphenols. This composition makes the oil ideal for both dietary consumption and cosmetic uses. The research highlighted the importance of selecting specific varieties for targeted applications, ensuring that the oil meets the required standards of quality and effectiveness. It also emphasized the role of variety and maturity in influencing the oil's composition, which is critical for producers aiming to cater to specific market demands.

Raut et al. (2015) explored the use of coconut oil in pharmaceutical applications, demonstrating that its unique fatty acid composition enhances drug solubility and skin absorption. The study suggested that coconut oil could be used in developing biocompatible materials for drug delivery systems, such as lipid-based formulations. These formulations can improve the stability and efficacy of medications, particularly for topical and transdermal applications. Coconut oil's non-toxic and moisturizing properties also make it suitable for enhancing the bioavailability of active ingredients in cosmetic products, thereby benefiting from its role as an emollient in skincare routines.

2.5. Coconut shell and its applications

Green coconuts (Cocos nucifera L.) are commonly consumed for coconut water and their shells are discarded as household waste. These shells are the potential constituents for valorization. The husk of the green coconut contains fiber and pith material which are rich in phenols and other functional components. Coconut shells are a carbon-rich, environmentally friendly solid fuel, making them a viable alternative energy source. According to studies, coconut shells are a valuable source of phytochemicals, most of which can be converted into value-added products. We herein review this conversion process and provide an outline of the chemical composition of green coconut shells. The possible value-added by-products are beneficial due to their high content of dietary fiber, phytochemicals, and antimicrobial and antioxidant activities. The compounds present in the shell can be utilized by many industries as a natural and economical source of phytochemicals, fibers, bio-fuels, absorbents, bio-ethanol, etc. Keeping in view these points, it is obvious that the green coconut shell has a wide variety of applications, and thus developing an efficient system to utilize the green coconut shell

adequately will help to completely utilize its potential benefits. Coconut shell and coconut husk biomass are mainly composed of lignin, cellulose and hemicelluloses (Borel et al., 2021). Increasing the rate of cellulose breakdown improves the porous structure of biochar (Li et al., 2020), whereas increasing the rate of lignin breakdown contributes to the formation of biochar with a high specific area, high FC content and fine aromatic structure (Jiang et al., 2020). The composition of lignin, cellulose and hemicellulose in a coconut shell and coconut husk biomass influences the characteristics of coconut shell and coconut husk biochar. Coconut shell biomass contains 6–10 wt% MC, 0–2 wt% ash, 72–77 wt% VM and 15–23 wt% FC, whereas coconut husk biomass contains 0–8 wt% MC, 1–5 wt% ash, 83–85 wt% VM and 15–16 wt% FC.

The coconut shell ash can withstand a temperature of up to 1500oC with a density of 2.05g/cm3. That means this ash can be use in production light weight MMCs component with good thermal resistance. Coconut shell possesses remarkable properties such as carbon-rich and environmentally friendly solid fuel to other biomass and coal materials; hence, it is possible to produce alternative energy from coconut shell biomass due to its several characteristics. Coconut shell biomass is directly used for thermochemical conversion mainly for charcoal production. The coconut shells present a low amount of complex heavy metals, functional groups and are said to have amorphous structures and well required morphological qualities. The feedstock can serve as a promising source of energy because of the good properties of solid-fuel and carbon source. The high content of fixed carbon (21.8%), carbon content (40%), and high energy content (19.4%) will yield a potential carbonaceous material (charcoal). The coconut shell biomass presents superior performance than other biomass in terms of energy and carbon content. Elemental analysis findings such as nitrogen (0.22%) and sulfur (0.17%) show that the biomass is sustainable with zero carbon emissions. Hence, the use of coconut shell biomass for charcoal production could be cost-effective and eco-friendly, because the biomass is abundant at a very low price, and the comprehensive quantitative-characterization of the biomass shows its potential for waste to energy applications through thermochemical technology.

2.6. Coconut husk

Coconut husk is a by-product of coconut growing that has long been used for a variety of purposes. Its fibre is used industrially as a raw material for ropes, mattresses, stuffing for chairs and insulation. Defibring waste (cocopeat) is greatly appreciated as a horticultural growing medium. The hygroscopic properties of coconut husk make it a good water absorbent material

that is very effective in increasing the water-holding capacity of a soil in dry periods (Liyanage *et al*., 1993; Sherin *et al.,* 2004; Subramanian *et al*., 2006). It can also concentrate nutrients, particularly potassium (K) and chlorine (Cl), which can be recycled in coconut plantations when nuts are dehusked in the field and the husks are left to rot on site (Ouvrier, 1984; Ouvrier *et al.,* 1978; 1985; Teoh *et al.*, 1986). However, leaving husks to rot at the foot of coconut palms on peat soils has two major negative effects: firstly, it causes a nitrogen (N) deficiency in neighbouring palms, and heaps of husk fragments provide shelter for the insect pest Sufetula, whose larvae attack coconut roots (Bonneau *et al*., 2007) During the peak production times, heaps of these King Coconut Husks (KCH) are dumped. Furthermore, the husks of locally consumed king coconut are discarded with no proper use at the selling points. As king coconut is harvested immaturely, the husk has no economic value as it cannot be used for coir pith and fiber. Moreover, it has also been identified that these husks with immature shells become breeding grounds for mosquitoes during the rainy period. Mainly, king coconut is exported as an organically certified product following the process of international certification for organic products. In organic cultivation, use of chemically formulated fertilizers are not permitted. Therefore, growers use organic sources of nutrients mainly through compost and manure. However, these sources are deficient in potassium (Tennakoon and Bandara, 2003). Furthermore, most of the coconut growing soils in Sri Lanka are very low in their potassium levels (Herath *et al*., 2007; Herath *et al*., 2008). Therefore, it is recommended to use a potassium source together with organic manure. Research conducted on potential use of potassium containing minerals/rocks such as mica and feldspar to meet potassium need of crops has shown that releasing of potassium from these materials is very slow (Cooray *et al*., 1992; Herath, 2014), while the demand for potassium by coconut is very high. Unavailability of organic potassium source therefore remains as a constraint for expanding organic coconut production. Even though some potassium sources like sulfate of potash (SOP) are allowed to use in organic plantations, availability of these sources are limited in the market. Generally, coconut husk contains a considerable level of potassium (Herath, 2014). However, it has been understood that direct application of king coconut husk introduces various practical difficulties such as slow decomposition of the immature shell and environmental problems due to water collection in the shells creating mosquito breeding grounds. Furthermore, the immature husk does not have higher moisture retention capacity compared to the mature coconut husk which makes a limitation of its use. Therefore, this study was conducted to investigate the possibility of developing an easy to use product from king coconut husks that can be used as a nutrient

source for coconut cultivation and test its impact on major soil properties after application into bulk soil

2.7. Coconut coir

India currently produces over 15,000 million coconuts per year. In addition to the utilization of endosperm for edible purposes and extraction of oil, the outer non-edible fibrous portion of the nuts (coconut husk) is used for extracting coconut. fibre or coir, which is commerciality utilized for making value-added products such as mats, geotextiles etc. In the husk. coconut fibres are seen tightly packed along with nonfibrous, fluffy and light weight croaky material known as coir pith or coir dust, which constitutes about 50-70 percent of the husk. The composition and properties of coir pith vary (Moorthy and Rao, 1998)Because of high fertilizer prices andenvirom11ental concerns associated with its use and with the enhanced emphasis on commercial horticulture and organic farming, recent years have witnessed growing interest in utilizing coir pith in a more productive way in agri horticulture (Pmbhu and Thomas, 2001). Coir pith has got many enviable characteristics. making it a highly potential resource if used after proper composting. Coir pith has very high moisture retention capacity of 500-600 per cent and can be as high as 1100% of dry weight (Evans *et al*., 1996). In a comparative study with coir pith and three types of saw dust, coir pith retained the maximum moisture after 90 days of composting (MlY.lh and Pdili, 1998). It has high potassium content and low bulk density and particle density. The low particle density is due to high specific surface and high specitic surface gives it high cation exchange capacity (CEC) (Mapa.and Kumara, 1995) Dyes are colored organic stuff generally applicable for thecoloration of fabrics, paper, cosmetics, wood, leather material, etc. (Hussaan *et al*., 2017). It is generally considered that most of the synthetic dyes contain such interemediates which are hazardous and carcinogenic in nature and after their application when released contaminate the environment (Khattab *et al*., 2020; Mansour and Ben 2021). These industries dispose of potentially toxic chemicals in water bodies and environment and produce allergic, toxic, carcinogenic, and harmful effects on the skin. The synthetic dyes while entering into water streams affect the whole food chain badly (Kiran *et al*., 2017; Hynes *et al*., 2020). So the world environmental institution like EPA, FAO, and ETAD after strict observations has decided to move towards natural products. Among natural products, natural dyes have unique color chemistry (Sigurdson *et al*., 2017; Thakker 2020). Major merits of natural dyes over synthetic dyes due to which natural dyes have been receiving more and more attention for applications in textile dyeing are eco-safe nature, renewability, biodegradability, and non-carcinogenic nature (Nathan and Rani 2021; Baseri

2021). Mostly natural dyes are plant-based and are extracted from the roots, bark, leaves, flowers, and fruits; some natural dyes are derived from animals, insects, fungi, bacteria, and mineral sources (Mongkholrattanasit *et al*., 2016). Most natural dyes possess antioxidant, anti-allergic, and antibacterial properties (Verma *et al*., 2021). The dyes have functional effects due to their excellent advantages and can be considered as green eco-friendly dyestuffs having wonderful UV protection, medicinal properties, and fluorescence properties (Hou *et al*., 2017; Verma et al., 2021). In textile industries, the use of natural dyes produces brighter, faster, fluorescent, appealing, softer, and soothing color shades and also has insect repellent, deodorizing, and flame-retardant properties (Rather *et al*., 2016; Mansour 2018; Kusumastuti *et al*., 2020). These colorants have some drawbacks such as low exhaustion yield and fastness properties. Mordants are used in natural dyeing to improve color characteristics and fastness properties. Mordants play a vital role in natural dyeing processes via fiber–mordant–dye interactions (Singh and Sheikh 2020). Two types of mordants are in use, i.e., chemical and bio-mordants. Bio-mordants form diverse colors as predictable from a mordant and hence offer the full potential to substitute metal salts in silk dyeing for ecological dyeing of textiles (Gholampour and Ozbakkaloglu 2020; Rani *et al*., 2020; Mansour *et al*., 2020; Khan *et al*., 2021) For isolation of colorants, the conventional extraction methods are eco-safer and greener, but conventional methods are time-consuming, not cost-effective, and laborious task (Rym *et al*., 2012; Guo *et al*., 2015). The modern extraction and coloration techniques such as ultrasonic irradiation (US), ultraviolet irradiation (UV), microwave irradiation (MW), plasma treatment, and gamma radiations have promoted the natural dyeing process with improving color strength (Mansour et al., 2016; Zahid *et al*., 2017). Among radiation tools, ultrasonic radiation serves as the most convenient and energy-saving modern method (Lei *et al*., 2021). These raysspeed up the extraction and dyeing process and are considered the most efficient and energy-conservative method (Islam *et al*., 2021; Sheikh *et al*., 2016). Ultrasonic irradiation (US) enhances the diffusion rate of dyes into textile material and dyeing rates via cavitation. When a fluid is exposed to US waves, small bubbles are produced which grow up and produce oscillation in the medium. These oscillations are the waves of high pressure, which are effective in the extraction of natural colorants in a short period (Guinot *et al*., 2009; Yang *et al*., 2017). The benefit of using US energy in textile dyeing is that it increases the absorption uptake of dyeing material by fabrics showing the sonication ability in dyeing at very low temperatures. US treatment in textile dyeing is being employed nowadays because the US treatment provide cleaner, greener, uniform, and heat effective energy source (Sadeghi-Kiakhani *et al*., 2020). Natural colorant was extracted using US treatment which not only has enhanced color yield

also color fastness ratings (Yaqub *et al*., 2020). Coconut coir (Cocos nucifera) that belongs to Arecaceae (Palm) family is found in Asia, Africa, America, etc. Coconut coir extract is used in diarrhea treatment, arthritis inflammation, and non-toxic and non-allergic for skin, and coconut is rich in nutrients (Singla and Jagani 2012). Coconut coir contains two types of fibers: white fibers and brown fibers. Brown fibers (husk) are thick, strong, have high abrasion resistance, and contain a brown color tannin dye as natural colorants and give a brown color to fabric (Madhu *et al*., 2015). The silk fiber is secreted by a silkworm that spins it around itself to form a cocoon and is used as a textile fiber. The composition of natural raw silk is consisting of fibroin (62.5–67%), sericin (22–25%), water, and mineral salts (Sashina *et al*., 2006). Silk fabrics are being used from the remote past in textiles due to their soft, smooth, and lustrous texture (Mahmoodi *et al*., 2010; Sharma *et al*., 2019). Previously it has been observed that the utilization of coconut coir as a source of natural brown colorant has been limitedly reported. Our research group for the first time has valorized the waste material in the form of coconut coir for useful work that is natural dyeing. The coconut coir has been explored as a source of natural brown dye under the influence of ultrasonic rays for maximum isolation and bio-mordanting for making process more green and clean. The current study comprised exploring the coloring matter of coconut fiber for silk dyeing by the use of ultrasonic irradiation. Moreover, the effect of different chemicals and bio-mordants was also studied

2.8. Coconut leaves

Soil is not an inexhaustible source of nutrients and hence, the nutrient depletion over a period of time will adversely affect the nut yield, if the soil is not replenished with the nutrients. The crop with a density of 175 palms/ha requires 353 kg/ha of N, P and K as per Central Plantation Crops Research Institute (CPCRI) recommendation. This is based on general recommendation from CPCRI for fertilizing the matured bearing palms at 500 g N, 320 g P and 1,200 g K/palm/year, to be applied in 2 split doses, viz. one-third in May–June and two-thirds in September–October (Nelliat, 1973). The annual nutrient export by various parts of the palm, viz. nuts, fronds, trunk, bunch and spathe, reported by different workers vary from 20 to 174 kg N, 2.5 to 20 kg P and 35 to 249 kg K/ha (Ramadasan and Lal, 1966; Ollangnier and Ochs, 1978), but there appears to be a general agreement on the ratio of N and K removed by the palms (1: 1.44–1.75).The nutrient supply from organic manure is slow and steady apart from very low nutrient loss and the availability of micronutrients coupled with the added advantage of improving soil physico-chemical and biological properties. Plantation crops produce huge amount of biomass for recycling in the form of suitable organic manure and account for more

than 30–50% of the produce (Nampoothiri, 2001) and have sufficient potential to benefit from natural farming and sustain their yield with low external input, as they produce considerable quantities of biomass for recycling. Vermicomposting is the method of composting the organic matter by earthworms under favourable soil moisture and temperature conditions. Earthworms can mediate decomposition of lignin as well as poly phenol and thus accelerate the humification process. The CPCRI, Kasaragod (Kerala) has identified a local strain of earthworm (Eudrilus sp.), similar to African night crawler, which is quite efficient in composting coconut leaves into granular vermicompost (Prabhu *et al*., 1998). Thus obtained vermicompost from coconut leaves has been found to play an important role in low external input resources, as one of the components of integrated nutrient management for sustaining soil health, fertility and crop productivity. Hence research work was initiated to study the impact of vermicompost substituting inorganic fertilizer on productivity and profitability of coconut. Maheswarappa *et al*., (2011) have described the effect of vermicompost in combination with inorganic fertilizer on yield components, yield and economics of coconut and in this paper its effect on growth, nutrient status, soil microbial population and sustainability of the yield is discussed.

2.9. Coconut trunk

Timber structures have been used for centuries due to their natural and aesthetic appeal. However, in recent years, the focus has shifted towards sustainable and eco-friendly building materials. One such material that has gained attention is coconut wood. Coconut wood is a by-product of the coconut industry and is an attractive alternative to traditional timber due to its fast-growing nature and superior properties. The coconut palm tree (Cocos nucifera) is a monocotyledonous species that belongs to the Arecaceae family. Coconut wood comes from the trunk of coconut palm trees, which are primarily grown in tropical regions around the world. The coconut palm tree is native to the tropical regions of Southeast Asia and Melanesia, but it has been widely cultivated and naturalized in many other parts of the world. Today, coconut palms can be found growing in tropical and subtropical regions throughout the world, including Africa, the Caribbean, South America, and the Pacific Islands. In some areas, coconut palms are an important cash crop, providing income and livelihoods for local communities. They are particularly well-suited to coastal regions with sandy soils and high levels of rainfall, as they require ample water and good drainage. However, coconut palm trees are also vulnerable to a number of pests and diseases, which can have devastating impacts on local populations. For example, the coconut rhinoceros beetle, a destructive pest that feeds on the sap of young palm trees, has caused significant damage to coconut plantations in parts of the Pacific region.

Overall, the distribution of coconut palm trees reflects their adaptability and value as a crop, as well as the complex ecological and economic factors that influence the growth and cultivation of agricultural crops around the world. Indonesia, the Philippines, and India are also major producers of coconut wood and timber. Additionally, there has been a growing trend in recent years towards using sustainable materials such as coconut wood, which may lead to an increase in production as demand for eco-friendly products continues to grow. It estimated that approximately 20 million cubic meters of coconut lumber is produced each year from harvested mature tree. Figure 1 indicate transverse section of a coconut palm stem. Coconut timber has many applications as both a structural and interior design material. The harder, high-density timber is suitable for general structural purposes such as pillars, trusses, rafting, furniture, window and door frames, floors, decking and floor joists. The construction industry provides the bulk of the demand for coconut lumber. In the construction of buildings, coconut lumber is used in large volumes as scaffolding and as form lumber. Selected and graded coconut lumber is also used as house posts, girders, trusses, door jambs and sidings (Fao.org). In research states that coconut wood is strong and can be used to make furniture or decorative items like picture frames and sculptures. In a study by, coconut wood is used as the main material for furniture design based on local culture.

Since coconut wood has robust, durable, and multifaceted properties, it is the best substitute for conventional wood. The construction material industry utilises high-density coconut wood to produce trusses, grid, windows frame, floor tiles, railing, while medium-density coconut wood shall be used for horizontal studs, ceiling joists, frames and lowdensity as non-loaded structures such as panels and wallboard . South Pacific countries namely, Fiji and Tonga, commercially invest the coco wood as a housing element. These countries use coconut timber to manufacture. Tongue and Groove (TG) flooring, architectural beams, decorative/structural columns, and parquet flooring and export to New Zealand and Australian markets. Based on the FAO 1997 estimation of the country-wise percentage of senile palm, Arancon concluded that 50 coconut palms/ housing units are sufficient. Hence, with 360 million senile palms, a total of 7.2 million housing units can be built up. Srivaro *et al*., reported that coconut wood is strongly related to density regardless of trunk's size and age and has superior qualities than conventional timber. The compression strength of normally coconut timber (with the density of 400-600kg/m3) in perpendicular to grain under oven dry and airdry conditions are 9.64 N/mm2 and 12.85 N/mm2 respectively and in parallel to grain, its compression strength under oven dry and airdry conditions are 12.41 N/mm2 and 9.64 N/mm2 respectively

Timber of coconut has several applications in the fields of construction material and interior design. The highest density timber is highly desirable for structural purposes such as decking, furniture, columns, floors, door and window frames, trusses, floor joists and rafting. Coir derived from the husk of the coconut is converted into Geotextile that is used in the construction of roads, later layered upon by coarse aggregates and bitumen. The shell of the coconut is utilized in making fillers, bricks and tiles. Coconut wood has been recognised as a promising and reliable alternative for several conventional materials. Likely to traditional materials, the stem of the coconut is robust, durable, and multifaceted, and frequently used due to its cost-effectiveness. The coconut palm consists of a smooth, slender stem, which grows to 25 meters tall with roughly, 100 cm – 150 cm diameter. The coconut woods are categorized into three parts namely, high-density wood (600-900 kg/m^3), medium-density wood present in the sub-dermal part (400-600 kg/m^3), and low-density wood that softcore present in the interior of the trunk (200-400 kg/m^3).

Table 2.1. Studies conducted using sprouted coconut

Sl. No.	**Study**	**Result**	**Reference**
1.	Focuses on producing wine from coconut sprout using saccharomyces cerevisiae under controlled fermentation for 20 days.	The study highlights the potential of coconut sprout wine as a novel fermented product with significant nutritional and sensory attributes.	Sreelekshmi, M.M.R., *et.al.* (2018)
2.	Conducted a study to characterize the biochemical and nutritional properties of coconut haustorium, a spongy tissue formed during germination.	The study suggests potential applications of coconut haustorium in nutritionally balanced formulations, particularly for lactose-intolerant children.	Manivannan, A., *et.al.* (2018)
3.	Investigated the chemical composition, volatile profiles, and antioxidant activities of coconut haustorium (CH) with varying transverse diameters.	Highlight the potential of CH as a raw material for functional foods and dietary additives.	Zhang, Y., *et.al.* (2022)
4.	Conducted a study to evaluate the nutritional and anti-nutritional	COD haustorium had lower anti-nutrient content, highlighting its	Manju et al. (2021)

	composition of haustoria from three coconut varieties: chowghat orange dwarf (COD), malayan green dwarf (MGD), and west coast tall (WCT).	potential as a rich and safe nutritive source for human consumption	
5.	Reviewed the nutritional and medicinal properties of haustoria from coconut and palmyra trees, highlighting their increasing significance.	Findings emphasize the potential health benefits and commercial opportunities of utilizing haustoria.	E. Raja Rajeshwari et al. (2024)
6.	Reveals their potential as nutraceuticals, with strong antibacterial, anti-inflammatory, antioxidant, and cytotoxic effects.	Coconut sprouts have higher levels of flavonoids and vitamin C, reduced lipid content, and can decrease starch concentration.	Valli, S.A. and Gowrie, S.U., 2020.
7.	Evaluated the effects of coconut sprout administration during pregnancy on the reproductive performance of Sprague-Dawley rats, focusing on parameters like body weight, fetal development, and hormonal changes.	Coconut sprout administration at 100 and 200 mg/rat/day reduced body weight, uterine weight, fetal number, and estradiol levels but improved the growth and development of uterine, placental, and mammary tissues.	Aiba, S., *et al.,* 2017
8.	Isolated and characterized luteolin, a flavone from the sprouts of *Cocos nucifera L.*, and evaluated its bioactive potential, particularly its anti-ulcer effects using in vitro models.	Luteolin demonstrated strong antioxidant, anti-inflammatory, and anti-ulcer activities, achieving 90.39% inhibition of gastric ulcer cells at an IC50 value of 30.09 µg/ml, showcasing its potential as a natural anti-ulcer agent.	Gowrie, S.U., 2021
9.	Explored the anti-cancer potential of phytoconstituents from *Cocos nucifera* sprouts, focusing on their ability to target acute myeloid leukemia (AML)-associated proteins through molecular docking techniques.	Dodecanoic acid, identified as the key phytoconstituent, exhibited a binding affinity of -7.09 kcal/mol with the PTPN11 gene, suggesting its potential as a lead compound for AML treatment, warranting further in vitro and in vivo studies.	Santhy, K.S., 2021.

10.	Evaluated the phytochemical composition and antioxidant potential of coconut cotyledon, comparing hot and cold percolation extraction methods.	Methanolic cold percolation extracts showed the highest secondary metabolite content and antioxidant activity across assays, with significant EC50 values, highlighting the cotyledon as a nutrient-rich source comparable to coconut endosperm.	Kannaian, U.P.N., *et al.,*2020.
11.	Optimized regeneration protocols for anther-derived coconut embryos by identifying key histological traits and BAP concentrations that improve sprouting and healthy plantlet development.	The study found that a 25-35 µm BAP concentration resulted in 51.5% sprouted embryos, compared to 22.7% in the control, and identified the sequential events of embryo differentiation, with healthy plants arising from embryos with single shoots.	Perera, P.I.P.,*et al*., 2020

2.11. Ideology after reviewing the literatures

The research conducted was broad for coconut meat, coconut water and other by-products. The research on sprouted coconut showed that it has high amount of antioxidant (Table 2.1). Despite these it was found that these sprouted coconuts were sold at a cheap price (roughly 1 rupee per nut). Farmers or sellers who markets coconut embryos often treat them as a byproduct of coconut harvesting, rather than a premium product, leading to lower profitability. Hence, various value addition of sprouted coconut is needed.

CHAPTER III

MATERIALS AND METHODS

This chapter outlines the methodologies employed to analyze the physico-chemical properties of coconut sprouts, develop value-added products like wine, and evaluate their quality. It provides detailed procedures for raw material collection, moisture content determination, and the analysis of parameters such as pH, color, and antioxidant activity. Additionally, the chapter describes the drying kinetics using cabinet tray drying and heat pump drying methods to optimize processing conditions. In the wine development process, varying concentrations of sucrose and yeast were used to assess their impact on the antioxidant content and overall quality. The quality screening involved microbial studies and physicochemical analyses to ensure product safety and consistency.

3.1. Physico-chemical properties of coconut sprouts

3.1.1. Raw material collection

Coconut sprouts, or Cocos nucifera, were collected from the instructional farm of KCAEFT, Tavanur. Low-quality sprouted coconut was stored in bulk at the farm; that was collected, and sprouts were recovered unbroken. The husk was removed using the Keramithra and the husk was separated using the butcher knife.

3.1.2. Moisture content determination

Moisture content was measured using an infrared moisture analyzer (SHIMADZU MOC63U Uni Bloc). The sample was placed on a precision sample pan inside the moisture meter, ensuring even distribution for accurate measurement. The high precision balance measured and recorded the initial weight of the sample. An infrared lamp heated the sample evenly, preventing burning or overheating. As the sample heated, moisture evaporated. The moisture meter continuously measured the sample's weight, tracking weight loss due to moisture evaporation in real time. The initial weight and real-time weight loss data were used to determine the moisture percentage (Azmi *et al.*, 2024).

Plate 3.1. Infrared Moisturemeter

3.1.3. Determination of color

The L, a, and b values, which represent the color properties of a sample, were measured using a Lovibond Tintometer, a widely used instrument for precise color analysis (Ghahjaverestani *et al.*, 2022). These values correspond to the components of the CIE Lab color space, a standardized system for defining color perception.

Fig 3.1. Lovibond Tintometer

3.1.4. Weight of each sprout

Four cleaned sprouts were selected and weighed individually using a digital weighing scale to obtain accurate measurements (Gatchalian *et al.*, 1994). The weight of each sprout was recorded in grams (g), and the average weight of a sprout was calculated from the individual measurements.

Plate 3.2. Digital weighing scale

3.1.5. Carbohydrate for Dried sample

Three sets of 0.1 g of the sample were prepared in 5 ml of 2.5N HCl and subjected to digestion in a boiling water bath for 3 hours. After digestion, the samples were neutralized using sodium carbonate (Na_2CO_3) and diluted to 30 ml with distilled water. The mixtures were then centrifuged at 6000 rpm for 15 minutes, and the resulting supernatant was analyzed in three different dilutions: undiluted (CS1), diluted to 10 ml with distilled water (CS2), and diluted to 100 ml with distilled water (CS3). For analysis, 4 ml of anthrone reagent was added to each test tube, and the tubes were heated in boiling water for 8 minutes. The absorbance was measured using a spectrophotometer at 630 nm (Hewitt, 1958).

Plate 3.3. Spectrophotometer

3.1.6. Antioxidant for dried sample

Three sets of 1 g samples were prepared in 20 ml of ethanol and vortex-mixed thoroughly. The samples were allowed to rest for three hours and then made up to 30 ml with ethanol. The mixtures were centrifuged at 6000 rpm for 15 minutes, and the resulting supernatant was analyzed under two dilutions: undiluted (S1) and diluted to 25 ml (S2). For analysis, 2 ml of S1 and S2 were transferred to separate test tubes, and 2 ml of DPPH reagent was added to each. The samples were vortex-mixed and incubated in the dark for 30 minutes. Finally, the absorbance was measured using a spectrophotometer at 517 nm (Ismail *et al.*, 2013).

Plate 3.4. Vortex mixer

3.2. Drying kinetics of sprouted coconut

A drying study was conducted in two methods: Cabinet tray drying and Heat pump drying to find the drying rate equation of best fit.

3.2.1. Cabinet tray drying

About 100 g of the sample were spread in thin layers on trays and kept inside cabinet tray dryer. The temperature of dryer is set at 60°C. The weight of the sprouts was measured every 30 minutes. The experiment continued till the weight of sample showed constant value. Once the drying is complete, the final moisture content of the leaves is measured (Sahari *et al.*, 2023).

Drying of coconut sprouts was performed using a Cabinet Tray Dryer, which was typically constructed with a double-walled chamber where the inner wall was made of stainless steel and the outer wall was coated with epoxy powder or made of stainless steel. It operated within a temperature range of Ambient +5°C to 250°C and included wire mesh adjustable shelves for batch flexibility. Heating elements were strategically placed in ribs at the bottom and sides to ensure uniform heat distribution. For enhanced operation, the dryer was equipped with an air circulating fan and a microprocessor-based PID temperature controller. The device worked on a power supply of 220/230 volts AC and was designed for consistent and efficient drying, making it suitable for industrial-scale applications in sprouted coconut valorization.

Fig 3.2. Cabinet tray dryer

3.2.2. Heat pump drying

About 100 g of the sample were spread in thin layers on trays and kept inside heat pump dryer. The temperature of dryer is set at 60°C. The weight of the sprouts was measured every 30 minutes. The experiment continued till the weight of sample showed constant value. Once the drying is complete, the final moisture content of the leaves is measured (Sahari et al., 2023).

Plate 3.5. Heat pump dryer

Drying of sprouted coconut is done using IKE Closed-Loop Heat Pump Dehydration Dryer, model no: WRH-100B, typically constructed from stainless steel, is capable of handling batches between 20 to 100 kg and operates at a maximum power of 2.6 kW consumption within a temperature range of 50-65°C. Its working principle involves drawing moist air from the drying chamber and passing it over an evaporator coil, where the moisture condenses and is removed. The dehumidified air is then reheated via a condenser coil before being recirculated back into the drying chamber to evaporate more moisture from the leaves. This process efficiently recycles heat, maintaining lower drying temperatures which preserve the quality of the leaves and minimize energy consumption.

3.3. Development of wine from coconut sprouts

3.3.1. Preliminary formulations

The collected sprouts were washed and the outer oil layer scrapped off. Then they were cut and grinded into small pieces. Different concentrations of sprout, sugar and yeast were added as per Table 3.1.

Table 3.1. Concentrations of sprout, sugar and yeast in each sample (preliminary formulations)

Sl. No.	Amount of Sprout (g)	Amount of sugar (g)	Amount of yeast (g)	Water (g)	Sample denotations
1	250	0	0	500	1:0:No yeast
2	250	125	10	500	1:0.5:Single yeast

3	250	125	20	500	1:0.5:Double yeast
4	250	250	10	500	1:1:Single yeast
5	250	250	20	500	1:1:Double yeast
6	250	0	10	500	1:0 Boiled and single yeast

Fig. 3.3. Flowchart of the wine making process

The flowchart outlines the step-by-step process for producing a wine from coconut sprout. It begins with collecting ingredients, specifically coconut sprouts, sugar, water, and yeast. The coconut sprouts are washed and cleaned thoroughly during the preparation stage to ensure hygiene. They are then mixed with water and sugar, after which the mixture is cooled to an appropriate temperature.

The process proceeds to primary fermentation, where yeast is added to the cooled mixture. The container is sealed with a muslin cloth to maintain anaerobic conditions, and fermentation is allowed to occur for seven days. After this initial stage, the liquid undergoes secondary fermentation, which involves straining the mixture to remove solid residues. The strained liquid

is transferred to a new, clean vessel, where it ferments for an additional 14 days to further develop flavor and alcohol content.

Finally, the wine enters the clarification and bottling phase. In this step, any remaining impurities or sediments are removed, and the clarified liquid is bottled for storage and consumption.

3.3.1.1. Analysis of pH

The pH analysis of each sample was conducted using a simple and effective method involving litmus paper. In this process, a strip of result

paper was carefully dipped into each sample, ensuring full contact with the liquid. The resulting color on the litmus paper was then compared against a standard pH chart, which provides a visual scale for interpreting pH levels (Hortvet, 1909). The chart typically ranges from 0 to 14, with the following classifications:

- 0–6: Acidic, with lower values indicating stronger acidity.
- 7: Neutral, meaning the solution is neither acidic nor basic.
- 8–14: Basic (alkaline), with higher values reflecting stronger alkalinity.

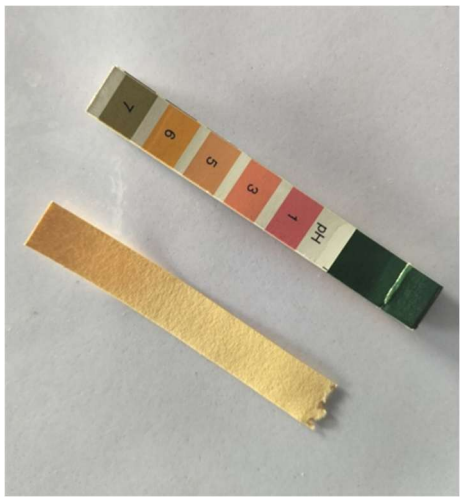

Plate 3.6. Litmus paper

3.3.1.2. Variables in wine making

- Independent variable: Sucrose content and Yeast content
- Dependent variable: Antioxidant value

Note: The amount of sprout in each treatment are the same

3.3.1.3. Analysis of antioxidant content in wine

Three sets of 1 mL samples in 9 mL ethanol were prepared. The samples were vortex mixed. Kept undisturbed for three hours. Made up the sample to 30 ml with ethanol. Centrifuge at 6000 rpm for 15 minutes. The supernatant was observed under two dilutions: one with zero dilution (S1) and the other made up to 25 ml (S2). 2 ml of S1 and S2 in different test tubes and 2 ml of DPPH reagent were added to each. The samples were vortex mixed. Kept for dark incubation for 30 minutes. Observed under spectrophotometer at 517 nm(Ismail et al., 2013).

3.3.1.4. Increasing the range of sucrose as a raw material in wine preparation

The amount of sucrose used for wine preparation was increased as amount of yeast had no effect in previous analysis. The combination is depicted in Table 3.2.

Table 3.2. Concentrations of sprout, sugar and yeast in each sample (Finalized formulations)

Sl. No.	**Amount of Sprout (g)**	**Amount of sugar (g)**	**Amount of yeast (g)**	**Sample denotations**
1	250	0	10	1:0:Single yeast
2	250	0	20	1:0:Double yeast
3	250	125	20	1:0.5:Single yeast
4	250	125	10	1:0.5:Double yeast
5	250	250	10	1:1:Single yeast
6	250	250	20	1:1:Double yeast
7	**250**	**375**	**10**	**1:1.5:Single yeast**
8	**250**	**375**	**20**	**1:1.5:Double yeast**
9	**250**	**500**	**10**	**1:2:Single yeast**
10	**250**	**500**	**20**	**1:2:Double yeast**

3.4. Screening of wine for quality analysis

Screening was conducted using a microbial study. The pour plate method using Sabouraud Dextrose Agar (SDA) is commonly used to enumerate and isolate fungal colonies (yeast and mold) from samples. To prepare the SDA, dissolve the agar powder in distilled water and autoclave at 121°C for 15 minutes. Cool the medium to 45–50°C before use. Prepare 12 samples by serial diluting them to a dilution factor of 10^3. Label each Petri dish with the sample number and dilution factor. Pipette 1 mL of the sample into the center of a sterile Petri dish, then add 15–20 mL of molten SDA, swirling gently for even distribution. Let the agar solidify in a sterile environment and incubate the plates at 25–30°C for 3 days. After incubation, count the colony-forming units (CFU) on each plate, considering the dilution factor.

Fig 3.4. Sabouraud Dextrose Agar (SDA)

3.4.1. Analysis of alcohol content

The ethanol content in wine was determined spectrophotometrically. The wine samples were diluted to bring the ethanol concentration within the measurable range (0.1%–1% v/v), and a preliminary distillation step was performed to isolate ethanol and remove potential interfering compounds. A series of ethanol standards with known concentrations (0.1%, 0.2%, 0.5%, 1%) were prepared by diluting ethanol in the same buffer solution used for the enzymatic reaction.

For each test, reaction mixtures were prepared by combining 1 mL of buffer solution, 0.5 mL of NAD+ (10 mM), 0.1 mL of ADH enzyme (prepared according to supplier instructions), and 0.2 mL of the wine sample or ethanol standard. The solutions were thoroughly mixed and incubated at 30°C for 10 minutes to ensure complete enzymatic reaction.

The absorbance of each reaction mixture was measured at 340 nm using a spectrophotometer, with a reagent blank serving as the reference. The absorbance values of the ethanol standards were plotted against their known concentrations to generate a calibration curve using linear regression.

The ethanol concentration in the wine samples was determined by comparing their absorbance values to the calibration curve. The final alcohol content of the wine was calculated by accounting for the dilution factor applied during sample preparation (Caputi *et al.*, 1968).

3.4.2. Analysis of sulphur dioxide content

The free sulfur dioxide (SO_2) content in wine was determined using the Ripper Method. A 15 mL wine sample was taken and mixed with distilled water and an alkaline iodine solution, prepared by combining iodine with potassium iodide in an alkaline medium (sodium hydroxide). A starch indicator was added to the mixture to assist in detecting the endpoint by forming a blue starch-iodine complex.

The wine sample was titrated with the iodine solution under constant stirring. During the titration, iodine reacted with the free SO_2 in the wine, forming iodide ions and sulfuric acid. The endpoint of the reaction was identified by the appearance of a stable blue color, indicating that all free SO_2 in the sample had reacted with the iodine.

The volume of iodine solution required to reach the endpoint was recorded, and the free SO_2 concentration in the wine was calculated using the following formula:

$$Free\ SO_2(mg\ /L) = \frac{V_1 \times N_i \times 32}{V_{sample}}$$

Where:

- V_1 = Volume of iodine solution used (mL)
- N_i = Normality of the iodine solution (equivalents of iodine per liter)
- 32 = Molecular weight of SO_2 (g/mol)
- V_{sample} = Volume of the wine sample (mL)

The calculated free SO_2 values were expressed in mg/L (Vahl *et al.*, 1980).

3.4.3. Analysis of peroxide value

The peroxide value (PV) of the wine sample was determined using a titration-based method.

A 15 mL wine sample was measured and transferred into a clean titration flask. A mixture of 5 mL glacial acetic acid and 5 mL chloroform was added to the sample to extract any peroxides and fatty substances. Next, 1 mL of freshly prepared potassium iodide solution (0.05 g/mL) was added to the flask. The solution was swirled gently to ensure proper mixing and initiate the oxidation of iodide ions (I−I^-I−) into iodine (I2I_2I2) by the peroxides present.

Immediately after the addition of potassium iodide, the released iodine was titrated with a standard 0.1 N sodium thiosulfate (Na2S2O3Na_2S_2O_3Na2S2O3) solution. The titration was carried out under constant stirring until the solution began to lose its yellow tint. At this stage, 1 mL of a 1% starch solution was added as an indicator, forming a blue starch-iodine complex. The titration was continued until the blue color completely disappeared, indicating the endpoint.

The volume of sodium thiosulfate used to reach the endpoint was recorded. The peroxide value was calculated using the formula:

$$PV\ (meq\ O_2) = \frac{V_{Na_2S_2O_3} \times N_{Na_2S_2O_3} \times 1000}{M_{sample}}$$

Where:

- $V_{Na_2S_2O_3}$ = Volume of sodium thiosulfate used (mL)
- $N_{Na_2S_2O_3}$ = Normality of sodium thiosulfate solution (equivalents per liter)
- 1000 = Conversion factor to scale the result to milliequivalents
- M_{sample} = Mass of the wine sample (kg)

The peroxide value of the wine was expressed in milliequivalents of active oxygen per kilogram (Héritier *et al.*, 2016).

CHAPTER IV

RESULT AND DISCUSSION

4.1. Properties of sprouted coconut

4.1.1. Moisture Content of Fresh Coconut Sprout

Using an infrared moisture meter, the moisture content of fresh coconut sprouts was determined to be 74.14%. This value highlights coconut sprouts' relatively high moisture content, which aligns with their fresh, fibrous nature and biological composition. Moisture content is a critical parameter in wine development as it influences the fermentability of the substrate, microbial activity, and overall yield of the wine(Martín-Gómez *et al.*, 2023).

The high moisture content of coconut sprouts plays a significant role in fermentation. It provides an ideal medium for yeast activity, as yeasts require sufficient water to metabolize sugars effectively and produce alcohol and other by-products. Additionally, the moisture level enhances the solubility of sugars and nutrients, facilitating the fermentation process. However, this high moisture content also presents challenges, particularly in storing and preserving raw materials. Coconut sprouts with high moisture levels are more prone to microbial contamination and spoilage if not processed promptly. Furthermore, excessive moisture can dilute sugar concentration, necessitating adjustments to the must (fermentable liquid) to achieve the desired initial sugar concentration for wine production.

Comparatively, the moisture content of coconut sprouts is similar to that of other fresh fruits and vegetables commonly used in wine production, such as grapes, papaya, and pineapple, which typically have moisture content ranging from 70% to 85%. This similarity underscores the potential of coconut sprouts as a viable raw material for wine development. The moisture content directly impacts the wine’s flavor profile, texture, and clarity. A high moisture level facilitates the extraction of aromatic and flavorful compounds during fermentation. It also supports the optimal water-to-sugar ratio needed for smooth fermentation, contributing to a balanced alcohol yield. Additionally, controlled moisture content ensures the desired body of the wine while minimizing the risk of cloudiness caused by excessive water content.

To maximize the potential of coconut sprouts for wine production, several recommendations can be made. Pre-fermentation adjustments, such as supplementing sugar sources or concentrating the must, may be necessary to achieve the desired Brix level, a measure of sugar

content. Preservation measures, such as freezing or drying, should be implemented immediately after harvest to prevent spoilage and maintain the quality of the coconut sprouts for fermentation. Finally, monitoring and controlling the substrate's moisture levels can help maintain consistency and ensure high-quality wine production.

Plate 4.1. Fresh coconut sprout

4.1.2. Color analysis

The L, a, and b color values of fresh coconut sprouts were determined using a Lovibond Tintometer, with a recorded value of 1.61. This value reflects the overall measurement of the color components, providing insight into the visual properties of the material. Understanding these color parameters is essential for evaluating the potential of coconut sprouts as a raw material in wine production. The value of 1.61 suggests a balanced color profile, with no significant shift toward any extreme tones, resulting in a neutral visual appearance.

The color characteristics of coconut sprouts hold particular relevance for wine production. First, the color of the raw material directly affects the visual appeal of the final wine (Dooley *et al.*, 2012). Coconut sprouts' neutral and balanced color profile suggests that the resulting wine will have a light and delicate appearance, potentially resembling pale yellow or light

golden hues, which align well with consumer expectations for white or specialty wines. Second, during the fermentation process, any pigments in the coconut sprout contribute to the wine's final color. Since the measured L, a, and b values indicate low pigmentation, the wine is likely to exhibit a light, transparent appearance, particularly with minimal processing or clarification steps. Finally, the wine's quality perception is closely tied to its clarity and color (Sáenz-Navajas *et al.*, 2011). Coconut sprouts' neutral tones can contribute to a visually appealing, clean, and simple product that may attract consumers seeking elegance in wine.

Despite its potential, there are challenges associated with the color profile of coconut sprouts in wine production. One key challenge is enhancing the color profile if a more pronounced hue is desired. In such cases, blending coconut sprouts with fruits that have higher pigmentation, such as berries or tropical fruits, or incorporating natural color enhancers like saffron or edible flowers could be effective (Xia *et al.*, 2024). Alternatively, fermentation conditions, such as temperature and oxygen exposure, can be manipulated to develop subtle golden hues in the final product (Killeen *et al.*, 2018).

Stabilizing the wine's color during fermentation and storage is another consideration. Techniques like cold stabilization, the use of fining agents, and the addition of antioxidants (e.g., ascorbic acid or sulfur dioxide) can help preserve the light and transparent appearance of the wine. Additionally, the lighter color profile of coconut sprouts presents an opportunity for creating distinctive wine varieties (Sreelekshmi *et al.*, 2018). Unlike intensely pigmented fruits like grapes or blackberries, coconut sprouts allow for the development of unique specialty wines that may appeal to consumers seeking novelty and innovation in their wine choices.

The balanced L, a, and b color values of coconut sprouts highlight their potential as a base material for producing light, transparent, and specialty wines. This subtle color profile offers an opportunity to create a distinctive product that stands out in the market. By pairing the wine with complementary flavors or natural enhancements, producers can further elevate its uniqueness. Coconut sprouts' neutral and delicate color characteristics position them as an innovative raw material in the wine industry, catering to consumers seeking fresh and aesthetically appealing wine options.

4.1.3. Weight of Fresh Coconut Sprout

The average weight of a single coconut sprout was measured to be approximately 90 g using a weighing balance. This measurement provides essential insights into the physical characteristics of the raw material and its implications for wine production. Understanding the weight of the sprouts is critical for determining raw material yield, optimizing extraction processes, and scaling production.

The weight of coconut sprouts plays a significant role in determining the raw material yield for wine production. With an average weight of 90 g per sprout, it is possible to calculate the number of sprouts required for a given batch size. For example, producing a standard fermentation batch requiring 10 kg of substrate would necessitate approximately 111 sprouts. This information is vital for scaling up production processes and estimating procurement costs for raw materials.

The weight also directly influences the extraction process, as heavier sprouts typically contain more moisture and fermentable components. This makes them advantageous for wine production, as they provide a higher volume of juice or extractable liquid. Consistency in sprout weight ensures uniform extraction and fermentation, which contributes to predictable product quality. Additionally, combining the weight with the measured moisture content of 74.14% reveals that each sprout contains approximately 66.7 g of water and 23.3 g of dry matter, including carbohydrates, fibers, proteins, and other nutrients essential for fermentation. The balance between moisture and solid content is crucial for achieving optimal sugar concentrations in the must (fermentable liquid).

The average weight of coconut sprouts offers practical advantages for batch preparation. For instance, calculating the weight of sprouts helps in scaling fermentation processes. If a batch requires 5 kg of sprouts, approximately 56 sprouts would be needed. Additionally, knowing the weight of the solid portion allows producers to assess sugar content and determine whether sugar supplementation is necessary to achieve the desired alcohol level.

The weight consistency also enhances processing efficiency. Uniform sprout weights simplify steps such as peeling, cutting, or blending, leading to consistent extraction rates. In contrast, significant variations in sprout weight could result in uneven sugar and nutrient concentrations, potentially affecting the fermentation process and final wine quality.

From an economic perspective, the average weight has direct implications for cost calculations, especially in large-scale production. Knowing that each sprout weighs 90 g enables accurate estimations of the total raw material required for achieving target wine volumes, ensuring efficient resource allocation.

While the average weight of coconut sprouts is beneficial, variations in weight can present challenges. Minor differences in weight may affect batch composition, so sorting sprouts by weight is recommended to maintain consistency. Optimization strategies could include prioritizing heavier sprouts with higher moisture content for juice extraction, while smaller sprouts may be reserved for other by-products, maximizing resource utilization. Additionally, weighing sprouts immediately after harvest is critical to prevent moisture loss through evaporation, which could reduce both the effective weight and the quality of the raw material.

The average weight of 90 g per coconut sprout, combined with its moisture content and other physical properties, underscores its suitability for wine production. The high water content and relatively consistent weight make coconut sprouts a reliable raw material for scaling fermentation processes. These findings provide a baseline for raw material handling, processing, and optimization, contributing to the development of efficient and high-quality wine production workflows.

Plate 4.2. Coconut sprout

4.2. Analysis of antioxidant in dried sample

The antioxidant activity of coconut sprout extracts was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay. The results indicated significant free radical scavenging capacity, with the activity varying across different sample dilutions.

Replicates	Sample	Absorbance	DPPH scavenging activity
R1	Blank	0.011	Nil
	S1 (No dil.)	0.339	86.2586137
	S2 (1:25)	0.925	6.50506688
	Control	2.467	Nil
R2	Blank	0.028	Nil
	S1 (No dil.)	0.395	84.19367747
	S2 (1:25)	0.9448	62.06482593
	Control	2.499	Nil
R3	Blank	0.033	Nil
	S1 (No dil.)	0.405	83.96674584
	S2 (1:25)	0.95	62.39113222
	Control	2.526	Nil

Table 4.1. Experimental Observations of Analysis of Antioxidant (Dried Sample)

For S1 (undiluted), the DPPH scavenging activity was the highest, averaging 86.26% across replicates, demonstrating the potent antioxidant potential of coconut sprout extracts. In contrast, S2 (1:25 dilution) exhibited a reduced activity of approximately 62.50%. The control sample consistently showed negligible DPPH scavenging activity, with absorbance values of 2.47 to 2.53, confirming the efficacy of the coconut sprout extracts in reducing free radicals.

The findings suggest that coconut sprouts can be a valuable source of natural antioxidants, contributing to their potential use in wine production. The high antioxidant activity, particularly in the undiluted extract, highlights the benefits of utilizing coconut sprouts for enhancing oxidative stability and health-promoting properties in the wine-making process.

4.3. Study of drying kinetics

The drying behavior of coconut sprouts under two different drying systems—cabinet tray dryer and heat pump dryer—was comprehensively investigated using five drying models:

Newton, Logarithmic, Henderson and Pabis (both logarithmic and non-logarithmic forms), Page, and Midilli-Kucuk. Each model's applicability was evaluated based on its statistical fit, the accuracy of predicting moisture ratio (MR) over time, and the efficiency of the drying process as indicated by the time required to achieve a target MR value.

The Newton model, one of the simplest exponential models, was first applied to both drying systems. In the cabinet dryer, this model yielded a drying rate constant of $k = 0.00733\ min^{-1}$ and an excellent coefficient of determination ($R^2 = 0.9844$), suggesting a strong agreement between predicted and experimental MR values. However, the drying process was relatively slow, requiring 628 minutes to reach a moisture ratio of 0.01. In contrast, the heat pump dryer exhibited a significantly higher drying rate constant ($k = 0.01481\ min^{-1}$) and a correspondingly faster drying time (311 minutes) to achieve the same final MR. While the R^2 was slightly lower (0.9720), the Newton model still proved to be a good fit, accurately representing the rapid initial decline in moisture during heat pump drying.

Plate 4.3. Dried Coconut Sprout

Building upon this, the Logarithmic model introduced two additional constants to increase model flexibility. For the cabinet dryer, the drying rate constant was estimated at $k = 0.009\ min^{-1}$, with the moisture ratio decreasing gradually and reaching 0.001 after approximately 521 minutes. The heat pump dryer, with a substantially higher $k = 0.027\ min^{-1}$, achieved the same MR level in only 189 minutes, confirming its superior performance. However, it was observed that this model may deviate at very low MR values due to complex drying behaviors such as surface hardening and secondary drying effects.

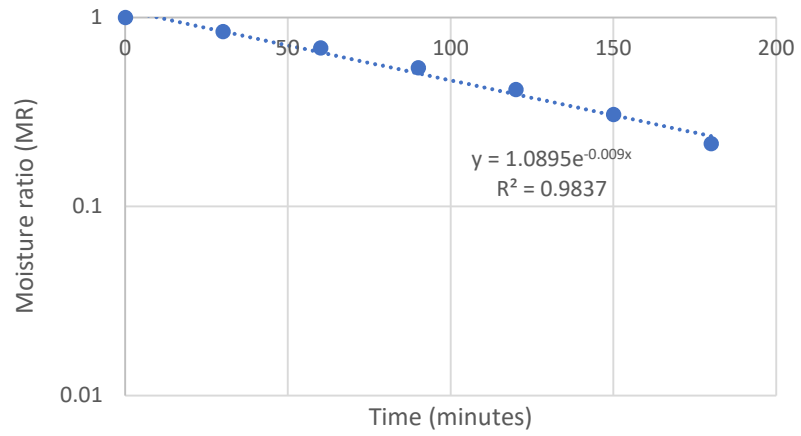

Fig. 4.1. Logarithmic model of drying kinetics in cabinet tray dryer

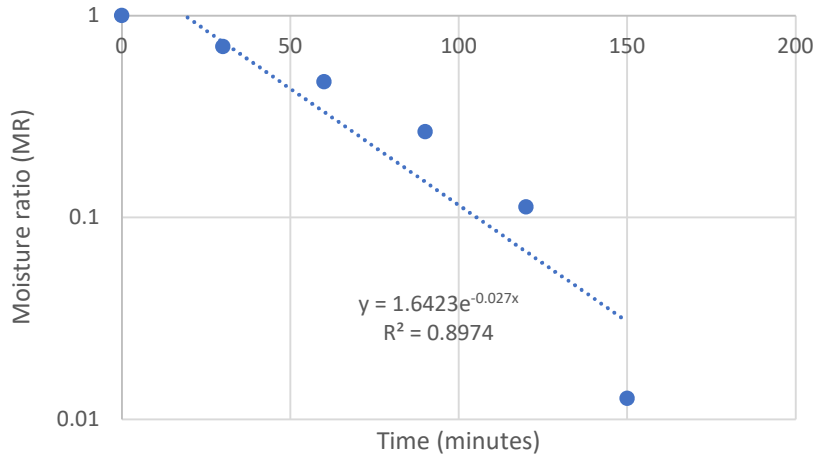

Fig. 4.2. Logarithmic model of drying kinetics in heat pump dryer

Next, the Henderson and Pabis model, both in its logarithmic and non-logarithmic forms, was applied. The cabinet dryer's logarithmic model fit produced a drying constant of k = 225.02 min^{-1}, and an R^2 of 0.9913, while the heat pump dryer model yielded k = 147.51 min^{-1} with R^2 = 0.9711. These high R^2 values confirmed the model's validity, particularly during the falling rate drying period dominant in biological products like coconut sprouts. The non-logarithmic application produced similarly strong results, with the cabinet dryer again slightly outperforming the heat pump dryer in terms of fit statistics. However, despite better fit accuracy in the cabinet system, the heat pump dryer continued to demonstrate faster moisture removal, consistent with operational observations.

The Page model, a modification of the Newton model incorporating an exponent n, further enhanced prediction accuracy. For the cabinet dryer, the model delivered an outstanding fit (R^2

= 0.9992), with parameters k = 0.00220 min^{-n} and n = 1.255, though the time required to reach an MR of 0.01 was exceptionally long (over 2300 minutes), reinforcing the system's slower kinetics. Conversely, the heat pump dryer, with k = 0.00277 min^{-n} and n = 1.386, achieved the same MR level in just 199 minutes. The inclusion of n > 1 in both systems affirmed the non-linear nature of moisture loss, making the Page model more representative of actual drying kinetics than simpler exponential models.

Finally, the Midilli-Kucuk model, which integrates both exponential and linear drying terms, offered the most precise and comprehensive description of the drying behavior. The cabinet tray dryer achieved a nearly perfect model fit with R^2 = 0.99992, k = 0.00323, n = 1.1237, and a minimal sum of squared errors (SSE = 4.1×10^{-5}). Although the drying time to reach MR = 0.01 was reduced to 283.5 minutes, it remained longer than the heat pump dryer. The heat pump system, with k = 0.00701, n = 1.1030, and R^2 = 0.99970, completed the drying process in 154.3 minutes, reaffirming its operational efficiency. The inclusion of a linear term in the model allowed for better representation of early and late drying dynamics, correcting slight over- or under-predictions seen in other models.

Across all modeling approaches, both dryers exhibited strong statistical conformity to the respective models, confirming the validity of the empirical and semi-empirical equations used. The cabinet tray dryer consistently yielded better model fits—slightly higher R^2 values and lower residuals—likely due to more stable and controlled drying conditions. However, the heat pump dryer repeatedly demonstrated higher drying rates and significantly shorter drying times, reinforcing its practical superiority despite slightly higher model errors. The Midilli-Kucuk model was particularly effective, capturing both the exponential and linear aspects of the drying process, and should be considered the most suitable for simulating and optimizing coconut sprout drying kinetics.

In conclusion, while the cabinet tray dryer provides greater predictive accuracy in terms of model fitting, the heat pump dryer excels in real-world drying performance. The Midilli-Kucuk model stands out as the most reliable modeling tool for capturing the complex, multi-phase drying behavior of coconut sprouts, and its parameters can serve as a valuable basis for industrial process optimization, energy savings, and quality control in agricultural drying applications.

4.4. Development of wine from sprout:

The development of wine from coconut sprouts involved preparing various formulations with differing concentrations of coconut sprout, sugar, yeast, and water to identify the optimal composition for effective fermentation and superior product quality.

4.4.1. Preliminary Formulations

The preliminary formulations focused on varying sugar content and yeast concentration, as detailed in Figure 4.4. These samples provided initial insights into the effects of sugar and yeast levels on the fermentation process. Samples with higher sugar content, such as the 1:1 formulation, showed improved fermentation activity characterized by a stronger aroma and increased microbial activity compared to sugar-free samples. Doubling the yeast concentration in samples like 1:0.5 and 1:1 further enhanced fermentation, leading to faster CO_2 release and a more robust flavor profile. In contrast, the boiled sample (1:0) displayed reduced fermentation activity, suggesting that heat-sensitive compounds in the coconut sprout might play a crucial role in supporting yeast metabolism.

4.4.2. Analysis of antioxidant in wine

The antioxidant activity of coconut sprout wine was analyzed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging method. This involved spectrophotometric measurements at 517 nm to determine the reduction in DPPH radical absorbance, an indicator of antioxidant activity. Two replicates of the supernatant were analyzed for each treatment (S1 and S2), with the results summarized.

The absorbance values of the wine samples varied across treatments, reflecting differences in antioxidant activity. Control samples showed a baseline absorbance of 1.150, while methanol (blank) exhibited negligible activity (0.005). The absorbance values for undiluted and moderately diluted samples (e.g., 1:0.5 and 1:1) indicated moderate antioxidant activity. However, boiled samples exhibited significantly reduced activity, suggesting the loss of heat-sensitive antioxidant compounds such as phenolics and flavonoids. At higher dilutions (1:1.5 and 1:2), the antioxidant efficiency diminished, possibly due to lower concentrations of active compounds.

The antioxidant efficiency of the wine samples was evaluated by measuring the percentage of DPPH inhibition. Both undiluted and moderately diluted samples exhibited effective inhibition, with the 1:0.5 (double) dilution achieving 69.13%, and the 1:1 (single) dilution showing

64.09%. Boiled samples demonstrated the highest inhibition, reaching 84.69%. These results highlight the significant influence of processing conditions and dilution levels on the antioxidant properties of coconut sprout wine.

Coconut sprout wine demonstrates promising antioxidant activity, which can be attributed to the presence of bioactive compounds such as phenolics and flavonoids, which are retained during fermentation. However, boiling the samples resulted in a substantial reduction in antioxidant activity, indicating the thermal sensitivity of these bioactive compounds. This emphasizes the importance of using natural processing methods to preserve the wine's health benefits. Additionally, at higher dilutions, the antioxidant efficiency decreased, suggesting that the concentration of bioactive compounds falls below an effective threshold for optimal antioxidant activity.

These findings underscore the potential of coconut sprout wine as a functional food product, rich in natural antioxidants, which could be valuable for applications in the food and beverage industries. Future research should focus on identifying specific antioxidant compounds using advanced analytical techniques, as well as exploring the role of microbial metabolites in enhancing antioxidant properties during fermentation.

Table 4.2 Antioxidant in wine

Sample	**Average absorbance**	**DPPH Scavenging activity**
1:0 (control)	0.408	72.05%
1:0 (boiled)	0.176	88.14%
1:0.5 (double)	0.355	75.73%
1:1 (single)	0.413	71.71%
1:1 (double)	0.353	75.87%
Control	1.150	nil

4.5 Finalized Formulations

Building on preliminary results, finalized formulations (Figure 4.5) explored a broader range of sugar and yeast concentrations to refine the fermentation process and improve sensory

qualities. Low sugar and yeast concentrations, as in 1:0 and 1:0.5, exhibited moderate fermentation with limited alcohol production and antioxidant activity due to restricted availability of fermentable substrates. Moderate sugar and yeast concentrations in the 1:1 formulations achieved balanced fermentation, yielding a desirable combination of alcohol content and flavor profile. Doubling the yeast concentration (1:1 with 20 g yeast) further enhanced fermentation due to increased yeast activity. The 1:1.5 formulations, with higher sugar content (375 g), improved sensory qualities and alcohol yield. However, high sugar levels in the 1:2 samples (500 g sugar) resulted in overly sweet wine due to incomplete fermentation, highlighting the need to optimize sugar-to-yeast ratios to avoid residual sweetness or stalled fermentation.

The preliminary trials highlighted the crucial role of sugar and yeast concentrations in achieving effective fermentation of coconut sprout wine. An increase in sugar content enhanced microbial activity up to an optimal level, contributing to a more efficient fermentation process. Similarly, higher yeast concentrations accelerated the fermentation process, facilitating a quicker conversion of sugars into alcohol. The finalized formulations further refined these parameters, revealing that a 1:1 ratio with double yeast and a 1:1.5 ratio with single yeast were the most effective combinations. These formulations successfully balanced alcohol production, flavor, and antioxidant activity. However, the 1:2 formulation, which had excessive sugar, resulted in residual sweetness and incomplete fermentation, indicating that careful optimization of the sugar-to-yeast ratio is essential for optimal fermentation.

The study identified the 1:1 (double yeast) and 1:1.5 (single yeast) formulations as the most effective combinations for producing coconut sprout wine with balanced alcohol yield, sensory qualities, and antioxidant activity. Increasing sugar levels enhanced fermentation and flavor up to a concentration of 375 g, but excessive sugar led to incomplete fermentation. Doubling the yeast concentrations generally improved fermentation but showed diminishing returns when applied to high-sugar formulations.

4.5.1 Quality Screening of Wine

4.5.1.1 Microbial study

The microbial enumeration of yeast and mold from the coconut sprout wine samples was conducted using the pour plate method on Sabouraud Dextrose Agar (SDA). The fungal colonies were incubated at 25–30°C for three days, and the colony-forming units (CFU) were counted for different sample dilution factors. The results are summarized in Table 2.

Table 4.3 Colony-Forming Units (CFU) of Fungal Isolates from Coconut Sprout Wine Samples

Dilution Factor	Single yeast (CFU × 10^3)	Double yeast (CFU × 10^3)
1:0	712	1851
1:0.5	738	637
1:1	22	No growth
1:1.5	No growth	No growth
1:2	No growth	No growth

The data indicates varying levels of fungal growth across the dilution series. The undiluted samples (1:0) yielded the highest CFU counts, particularly in the double culture (1851 × 10^3 CFU). Dilutions at 1:1.5 and beyond showed no fungal growth, indicating that the microbial concentration in the samples was reduced below the detection threshold at these dilutions.

The microbial enumeration results provide valuable insights into the fungal load during the wine fermentation process from coconut sprout. Both single (712 × 10^3 CFU) and double cultures (1851 × 10^3 CFU) in the undiluted samples exhibited substantial fungal growth, indicating a high initial load of yeast and mold in the raw coconut sprout sample, which likely contributed to the fermentation process. In the dilution experiment, the fungal growth remained relatively high in both single (738 × 10^3 CFU) and double cultures (637 × 10^3 CFU) at a 1:0.5 dilution, although it decreased significantly compared to the undiluted samples, probably due to the lower concentration of the inoculum. At a 1:1 dilution, the fungal growth in the single culture dropped dramatically to 22 × 10^3 CFU, and no growth was observed in the double culture. This suggests that there is a dilution threshold where fungal propagation is significantly inhibited.

At higher dilutions of 1:1.5 and 1:2, no fungal colonies were observed, which indicates that the concentration of fungal spores or cells in these samples was below the limit of detection or was insufficient to support growth under the given conditions. The SDA medium and incubation conditions were optimized for fungal growth, meaning that the absence of colonies in higher dilutions is likely due to the low microbial load rather than environmental factors. Interestingly, double cultures consistently showed higher CFU counts in the lower dilutions (1:0 and 1:0.5), which may indicate synergistic effects or differences in sample handling.

The results suggest that coconut sprout naturally harbors yeasts and molds that are conducive to fermentation. However, it is essential to carefully monitor and control microbial activity to maintain product quality and prevent spoilage. The absence of fungal growth at higher dilutions offers an opportunity to optimize fermentation by controlling microbial concentrations, ensuring that beneficial yeasts dominate the process. Future studies should focus on identifying the specific strains of yeast and molds involved in fermentation and their contributions to flavor, aroma, and alcohol production. Additionally, the influence of varying environmental factors, such as temperature and pH, on fungal growth should be explored to optimize fermentation conditions. The study establishes a clear relationship between dilution factors and fungal growth in coconut sprout wine samples. The findings emphasize the importance of initial microbial load in driving fermentation processes and provide a foundation for targeted microbial management to improve the quality of wine production.

Plate 4.4. Samples Prepared for Microbial Study

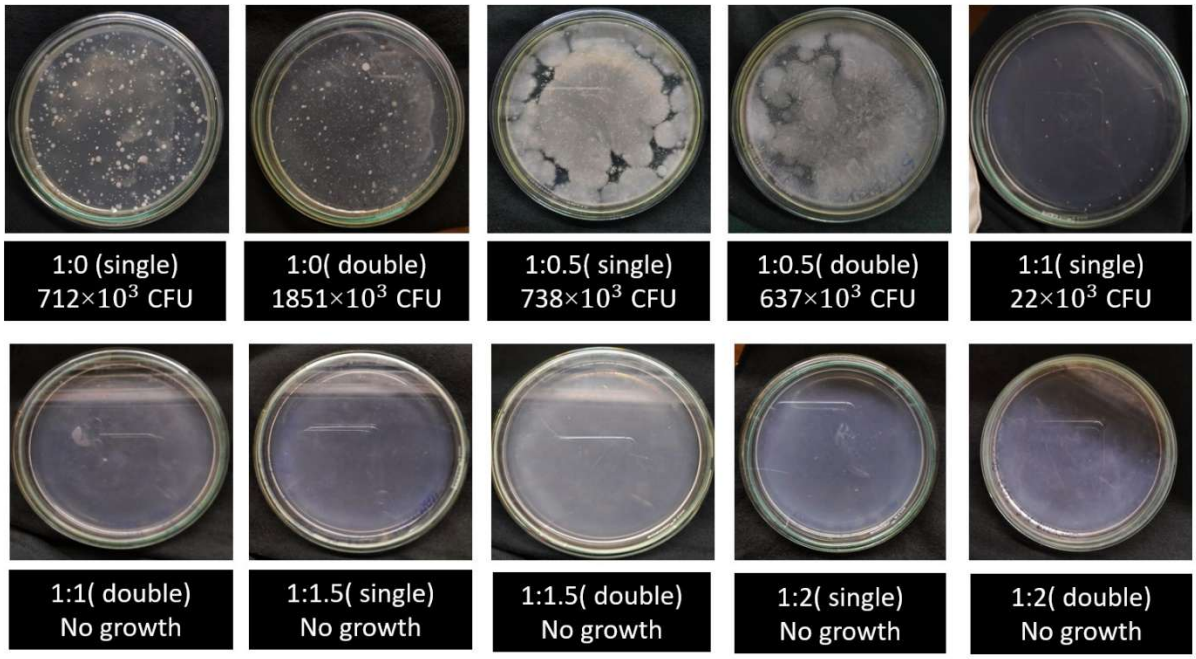

Plate 4.5. Microbial study of the samples

4.5.1.2 Screening of wine for chemical analysis

The chemical composition of wine samples with varying concentrations was analyzed to evaluate their quality, safety, and potential consumer appeal. The parameters assessed included alcohol content, peroxide value, and sulphur dioxide concentration.

4.5.1.2.1 Alcohol Content

The alcohol content in the wine sample (Concentration 1:2(single yeast)) analyzed and recorded at 2.7%. This classifies the beverage as a low-alcohol product, indicating either a naturally light fermentation process or a deliberately controlled alcoholic fermentation. Such low alcohol levels are commonly observed in fruit-based or non-fortified wines tailored to health-conscious consumers or those preferring reduced alcohol intake.

In comparison, the wine samples analyzed for second time demonstrated slightly higher alcohol concentrations. The wine of concentration 1:2(single) recorded an alcohol content of 3.47%, while wine of concentration 1:1.5(single) showed a marginally lower value of 3.37%. Although higher than the previously tested sample (2.7%), both readings remain significantly below the standard range of 8–15% observed in conventional wines. The slight variation (0.10%) in alcohol levels between the two samples can be attributed to natural fluctuations in fermentation

efficiency, sugar content in raw materials, or differences in fermentation parameters such as time and temperature.

4.5.1.2.2 Peroxide Value

Peroxide value serves as an indicator of lipid peroxidation, which can lead to oxidative spoilage and undesirable flavor changes. A peroxide value of 0.0% was observed in both instances of wine of concentration 1:2(single). This result confirms the absence of oxidative degradation and implies that the wine samples were produced using fresh raw materials and maintained under proper storage conditions. The peroxide value for wine of concentration 1:1.5(single) was not reported; however, assuming similar production practices, it is likely to exhibit comparable oxidative stability.

4.5.1.2.3 Sulphur Dioxide Content

Sulphur dioxide (SO_2) is widely employed in winemaking as a preservative to inhibit microbial growth and prevent oxidation. In both instances of wine of concentration 1:2(single), sulphur dioxide levels were consistently measured at 0.032 mg/L. This value is considerably below the permissible limits set by regulatory agencies such as the Food Safety and Standards Authority of India (FSSAI). The minimal concentration observed suggests either limited use of chemical preservatives or natural sulphite production during fermentation. This feature is particularly advantageous for consumers with sulphite sensitivity and aligns with the growing demand for clean-label or additive-free beverages. Sulphur dioxide data for wine of concentration 1:1.5(single) was not available, which limits direct comparison; however, consistent production methods likely yield similar outcomes.

4.5.1.2.4. Overall Assessment

All wine samples analyzed during the two testing intervals demonstrated acceptable chemical quality, with alcohol content in the low to moderate range, absence of oxidative spoilage (as evidenced by peroxide values), and safe levels of preservatives. The variations in alcohol content were minor and within the expected range for natural fermentation processes, suggesting a well-regulated and uniform production system.

The low levels of both alcohol and sulphur dioxide, coupled with the absence of peroxide, indicate that the wines are formulated to cater to health-conscious consumers seeking natural or minimally processed alternatives. These results support the hypothesis that the wines were

produced through a small-scale, carefully managed fermentation process, ensuring product stability, safety, and consistency in quality.

CHAPTER V

CONCLUSION

The research conducted on the Development and Evaluation of Coconut Sprout Valorization sheds light on the immense potential of coconut sprouts as a sustainable and valuable resource within the food processing industry. This study systematically evaluated the physicochemical properties, drying kinetics, and potential product applications of coconut sprouts, demonstrating their nutritional and economic significance.

Coconut sprouts, often considered a by-product, are a rich source of nutrients such as medium-chain fatty acids, vitamins, minerals, and fiber. Despite their potential as a delicacy and healthful ingredient, they remain underutilized in the market. This project aimed to bridge the gap by exploring innovative approaches to enhance their usability and value. By employing advanced drying technologies and processing methods, the study has contributed to improving the shelf life and marketability of this resource. The findings highlight the feasibility of transforming coconut sprouts into high-value products, such as wine, which can cater to niche markets seeking unique and health-conscious options.

The alignment of this project with the mission of the Coconut Development Board—focusing on value addition in coconut processing—emphasizes its relevance to current industry goals. The work undertaken addresses significant challenges, such as the rapid perishability of sprouts and the lack of awareness regarding their benefits. Through detailed analysis and experimentation, the study showcases practical solutions for improving the economic viability of coconut farming, which is vital for sustaining this important agricultural sector.

The key findings of the study include:

- Among the drying techniques studied, the heat pump dryer performed better than the cabinet tray dryer in terms of efficiency.
- The Midilli-Kucuk model provided the best fit for describing the drying behavior of the sprouts.
- Antioxidant tests revealed that coconut sprouts possess strong free radical scavenging properties
- Fermenting the sprouts into wine was successful, producing a beverage with low alcohol content, good antioxidant activity, and minimal chemical additives—meeting modern consumer preferences for natural, low-alcohol drinks.

- The study demonstrated a practical approach to reducing waste and improving the shelf life of coconut sprouts, creating new opportunities for value addition and income generation for coconut farmers.
- By turning an underutilized part of the coconut into a marketable product, the project promotes sustainable use of agricultural resources and supports eco-friendly practices.

One of the key strengths of this study was the institutional support provided by the instructional farm at KCAET, which generously supplied the raw materials required for the experiments. This collaboration highlights the importance of resource sharing and institutional backing in advancing academic research. Such partnerships not only enhance the scope of research but also pave the way for practical implementations that benefit local farmers and industries.

The study's findings also underline the need for increased awareness and education about the value of coconut sprouts. Targeted efforts to educate consumers and industries about their nutritional benefits and culinary versatility can significantly enhance their market presence. Furthermore, this research paves the way for exploring other value-added products from coconut sprouts, broadening the horizon for innovation in coconut processing.

In addition to its economic and nutritional implications, this research contributes to environmental sustainability. By utilizing coconut sprouts—often discarded as waste—this project promotes waste valorization and underscores the role of sustainable practices in agriculture and food processing. Encouraging such practices can lead to reduced wastage and a more efficient use of resources, aligning with global goals for sustainable development.

Looking forward, the insights gained from this study open avenues for further research and development. Future work could focus on scaling the processing technologies, assessing the commercial viability of coconut sprout-based products, and exploring consumer preferences. Collaborative efforts with industry stakeholders, including small-scale farmers, processors, and retailers, can facilitate the commercialization of these products and foster a sustainable coconut farming ecosystem.

In conclusion, this study has successfully demonstrated the potential of coconut sprouts as a valuable resource, offering economic, nutritional, and environmental benefits. By integrating innovative processing techniques and addressing existing challenges, the project contributes to creating a more sustainable and profitable future for the coconut industry. The outcomes serve

as a stepping stone for future endeavors, inspiring innovation and value addition in agricultural practices, particularly in underutilized by-products like coconut sprouts.

CHAPTER VI

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VALORISATION OF COCONUT SPROUT

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ABSTRACT OF PROJECT REPORT

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ABSTRACT

The research titled "Development and Evaluation of Coconut Sprout Valorization" focuses on the underutilized potential of coconut sprouts, an emerging by-product of coconut farming, and their transformation into value-added products. Coconut (Cocos nucifera), a vital crop in tropical and subtropical regions, is globally recognized for its versatility and economic significance. Among its many parts, the coconut sprout, often regarded as a by-product, holds substantial nutritional value due to its rich composition of medium-chain fatty acids, vitamins, minerals, and fiber. However, its limited shelf life and lack of market awareness pose challenges to its widespread utilization.

This study aimed to address these challenges by investigating the physicochemical properties of coconut sprouts, analyzing their drying kinetics using different drying methods, and exploring their application in developing innovative products such as sprout-based wine. The experiments employed advanced drying technologies to extend the shelf life of sprouts while preserving their nutritional integrity. The project also assessed the role of sucrose and yeast content in wine fermentation and evaluated the antioxidant properties and microbial quality of the final product.

The findings revealed that coconut sprouts possess significant potential for inclusion in high-value food products. By aligning with the Coconut Development Board's mission of promoting value addition in coconut processing, this research underscores the economic, nutritional, and environmental benefits of sprout valorization. Furthermore, the study highlights the importance of institutional support, as the raw materials provided by the KCAET instructional farm enabled successful project execution.

This research contributes to sustainable agricultural practices by promoting waste reduction and resource utilization. It also provides a foundation for future studies, emphasizing the need for innovative technologies to improve the marketability of sprouted coconuts. With targeted efforts in consumer education and industry collaboration, coconut sprouts can emerge as a valuable product in both local and global markets. The outcomes of this project not only enhance the economic viability of coconut farming but also align with broader goals of sustainability and innovation in food processing.