DEVELOPMENT OF MICRONUTRIENT MANGO NECTAR FORTIFIED WITH MORINGA (*MORINGA OLEIFERA. LAM)* LEAF EXTRACT

BY

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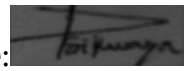
Signature:  Date:4/09/2023

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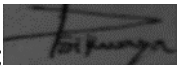
Signature:  Date:14/02/2023

DEDICATION

This work is dedicated to my family members, who have been an inspiration to me.

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LIST OF ABBREVIATIONS

ANOVA:	Analysis of Variance
AOAC:	Association of Analytical Chemists.
G.A.E:	Gallic Acid Equivalent
Q.E:	Quercin Equivalent
DCPIP:	Dichlorophenol indophenol
d.w:	Dry Weight Basis
f.w:	Fresh Weight
KEBS:	Kenya Bureau of Standard
M.L.E:	Moringa Leaf Extract
M.O.L. E	*Moringa oleifera* leaves extracts
TTA:	Titratable Acidity
TSS:	Total Soluble Solids
USAID:	United States Agency for International Development
UV/VIS:	Ultraviolet-visible
WHO:	World Health Organization
FAO:	Food and Agricultural Organization
HCD:	Horticultural Crops Directorate
ADF:	Acid Detergent Fiber
KALRO:	Kenya Agricultural and Livestock Research Organization
FPO:	Fruit Products Order
FSSAI:	Food Safety and Standards Authority of India

GENERAL ABSTRACT

Kenya is Africa's third-largest mango grower, but postharvest losses have increased due to fruit perishability, limited cold storage and insufficient value addition. Mango nectar contains vitamins and minerals but not enough micronutrients and phytochemicals. *Moringa oliefera* leaves contain vitamins and nutrients that could increase the nutritional value of mango nectar. The present study's overarching goal was to create mineral-rich mango nectar enriched with moringa leaf extract. Mango samples from two commonly produced types, Apple and Tommy Atkin, as well as moringa leaves, were collected from smallholder farmers in Machakos and Kajiado and delivered to the University of Nairobi's Faculty of Agriculture. After the mango pulp was extracted, 25% of the mango pulp was blended with 0, 10, 12.5 and 15% of *Moringa oliefera* leaf extract to create eight unique products: four from Apple mango fruit pulp (F1 control, F2 blended with 10% moringa leaf extract, F3 blended with 12.5% moringa leaf extract, and F4 blended with 15% moringa leaf extract), and four from Tommy Atkin mango (F5 control, F6 blended with 10% moringa leaf extract, F7 blended with 12.5% moringa leaf extract and F8 blended with 15% moringa leaf extract), which were subjected to sensory analysis to establish the best formulation before examination of chemical, nutritional, and phytochemical features. The best acceptable product (F1control and F3 blended with 12.5% moringa leaf extract for apple mango fruit and F5 control and F6 blended with 10% moringa leaf extract for Tommy mango pulp) was used to analyze the microbiological quality, physicochemical and phytochemical properties at 30-day intervals for 90 days of storage using the Association of Official Analytical Chemists' Methods.

The results showed a significant difference ($p<5\%$) between the two mango pulps and moringa leaf extract. According to the findings, mango pulp contains bioactive phytochemicals such as phenolics (31.47 for Apple mango pulp and 28.38 mg for Tommy mango pulp GAE/100g DW), flavonoids (11.46 for Apple mango pulp and 9.43 mg for Tommy mango pulp QE/100g DW),

calcium (48.05 for Apple mango pulp and 33.2mg/100g DW for Tommy mango pulp), iron (5.22 for Apple mango pulp and 9.36 mg/100g DW for Tommy). The results showed that moringa leaf extract was high in calcium (910.18 mg/100 g DW), iron (90.26 mg/100 g DW), zinc (28.88 mg/100 g DW), total phenolics (12787.3 GAE mg/100 g DW), and flavonoids (8025.1 QE mg/100 g DW). The mango nectar enriched with moringa leaf extract showed that there were significant differences (P<5%) among apple-mango nectar blended with 12.5% moringa leaf extract and Tommy Atkin mango nectar blended with 10% moringa leaf extract. In comparison to Tommy Atkin mango nectar enriched with 10% moringa leaf extract, which only contained 34.26 mg/100g of calcium, 2.01 mg/100g of iron, and 7.19 mg/100g of zinc, apple mango nectar enriched with 12.5% moringa leaf extract had greater calcium (39.89 mg/100g), iron (3.14 mg/100g), and zinc (8.85 mg/100g).

After 90 days of storage, there were significant differences (p<5%) between apple-mango nectar mixed with 12.5 percent moringa leaf extract and Tommy Atkin mango nectar combined with 10% moringa leaf extract. Tommy Atkin mango nectar blended with 10% moringa leaf extract had higher significant nutritional losses of vitamin C (72.622% and 59.967%), total phenolics (63.57% and 58.193%), and flavonoids (59.597% and 49.856%) under room and chilling temperature, respectively; whereas losses for Apple mango nectar blended with 12.5% moringa leaf extract were: vitamin C (44.634% and 36.524%), total phenolics (38.427 and 15.729%), and flavonoids (22.654% and 11.305%). Moringa leaf extract's antifungal characteristics ensured that mango nectar was yeast- and mold-free after 90 days. Under ambient and chilling temperatures, results showed that Tommy Atkin mango nectar enriched with moringa leaf extract lost more than 50% of its vitamin C, total phenolics, and flavonoids after 90 days, while apple mango nectar lost less than 50%, making it suitable for commercial purposes. *Moringa oliefera* leaf extract helps increase the mango nectar's nutritional value and is therefore commendable for value addition. Tommy Atkin mango pulp might be used to make

energy drinks due to its high sugar content, but apple-mango pulp is suggested for nectar production due to its concentrations of vitamin A, vitamin C, calcium, zinc, total phenolics, and flavonoids making it superior.

CHAPTER ONE: INTRODUCTION

1.1 Background information

Tropical and subtropical conditions are ideal for the growth of the mango (*Mangifera indica L.*), a plant belonging to the Anacardiaceae family (Sidhu, 2017). The mango is a necessary and common tropical fruit that is categorized as a delectable drupe and has a single large seed. It is encased in a fleshy mesocarp (Sidhu, 2017). Globally, mango is a widely consumed tropical fruit (Dixit et al., 2018). Mango output worldwide averaged roughly 25.1% metric tons yearly, with a 2.6% yearly growth rate (Okoth et al., 2013b). Asia produces the majority of the world's mangoes—76.9% of total production—followed by the Americas (13.38%), Africa (7.72%), Europe (1%), and maritime nations (1 percent) (Jahurul et al., 2015). Kenya's traditional mango-producing districts along the coast are no longer the only places where the fruit is grown; it is now the nation's second-largest commercial crop, behind only bananas (Owuor, 2015). With over 42,000 ha of mango orchards, eastern Kenya leads the way in mango production (Musyoka, 2020). According to Horticultural Crops Directorate HCD (2018), thirteen central Counties in Kenya produce mangoes, with Makueni producing more than 30% of the total production. According to Food and Agriculture Organization data, mango is the second-most important crop after banana in terms of land area and output (FAOSTAT, 2015). Mango yield has increased steadily, while postharvest losses have increased by 40 to 50 percent (PHL) (Mujuka et al., 2020). The substantial postharvest losses result from inadequate postharvest management, storage technology, processing facilities, and market access. To reduce postharvest losses, developing Countries must enhance producers' ability, improve infrastructure to enable market access, increase value chains and enhance postharvest technologies by converting mango fruit into stable products like as pulp, nectar, flaks, juices, powder, and won, as well as coordinating supply chain players (Hodges et al., 2011).

In 2015, cultivable land covered 46,364 hectares (ha), producing 779,147 metric tons (MT), whereas, in 2016, cultivable land covered 49,098 ha, producing 806,575 MT (Mujuka et al., 2020a). In 2014, the market value of mangoes in Kenya was 416,194,332 USD, representing 26% of the total actual value of horticulture products (HCD, 2013). The bioactive chemicals in mango fruit, such as polyphenols, function as antioxidants, anti-inflammatory, anticarcinogenic, and anti-aging agents. Vitamins A and C, both antioxidants, are abundant in this fruit. Mango is said to be high in phytochemicals and nutrients, thereby classifying it as a "super fruit," a term used to describe the potential health benefits of certain nutritious fruits (Babarinde et al., 2019a).

About 83% of a mango's weight comprises carbohydrates and minerals, including calcium, iron, and potassium (Leghari *et al*., 2013; Babarinde *et al*., 2019). Mangoes are perishable with a short shelf life (Kour et al., 2018)

Pasteurization is widely used to sterilize foods with high acidity, aiming to lower the bacteria population and inactivate endogenous enzymes (pH>4.6) (Barrett and Lloyd, 2012). This procedure makes it possible to produce a superior, shelf-stable product at room temperature (Liu et al., 2020) Mango juice contains essential minerals, vitamins, and other nutritive constituents; nectar juice is a refreshing beverage with no carbonation and few preservatives and is a critical vitamins and minerals source (Mingire *et al*., 2016).

In addition, the quality of mango fruit juice degrades over time (color, flavor, and nutritional value), which impacts consumer acceptance (Oliveira et al., 2012). Blending mango nectar with moringa leaf extract, which is known to be high in micronutrients (calcium, iron, and zinc), phytochemicals (flavonoids and phenolic acid), protein, vitamins C and A, may be used to increase the nutritional content of mango nectar regardless of processing method and storage period (Suphachai, 2014). *Moringa oleifera* leaves contain seven times as much vitamin C as oranges and 25 times more iron than spinach. Additionally, it offers fifteen times as much

potassium as bananas and nine times as much protein as yogurt (Dixit et al., 2018). According to (USAID, 2017), chronic malnutrition affects approximately 1.82 million Kenyan children out of a total population of 7 million (26 percent). Mango juice mixed with moringa leaves extract will be an essential factor in combating malnutrition in the community. This study set out to increase the amount of vitamin A, vitamin C, total phenolics, flavonoids, calcium, iron, and zinc in mango nectar as well as to assess any nutritional changes that took place while the enhanced mango nectar was being stored.

1.2 Statement of the Problem

In Kenya, mango production significantly increased over time, rising from 26% to 29.6% in 2011 (Musyimi,2013). The projected annual mango production in Kenya is 1,024,500 metric tons, however, due to inadequate value-adding capabilities during output surpluses, these production increases have been accompanied by significant postharvest losses, estimated at over 50%, thereby raising waste management costs and contributing to greenhouse gas emissions (Aulakh and Regmi, 2013; Mujuka *et al*., 2020; Chikez et al., 2021).

Despite the fact that the majority of mangoes are consumed fresh, some (1 to 5% of mango fruit) is processed by firms such as Sunny Mango Processors and Milly Processors. These businesses process mango into concentrates, jam, and juice (Musyimi 2013b). Mango pulp, nectar, juice, chips, mango lather, and other shelf-stable goods can be made from perishable fruit to decrease postharvest losses from mangoes. Mango nectar helps lessen the loss of mango fruit (Xess *et al*., 2018).

One of the most famous and widely used items made from mango fruit is mango nectar. Mango nectar is abundant in potassium, provitamins A and B, and C, but it is deficient in other key micronutrients like calcium, zinc, and iron, as well as phytochemicals like flavonoids and total phenolics (Lebaka *et al*., 2021b). There was also no published research on mango fruit pulp blended with moringa leaf extract. The leaves of the *Moringa oleifera* plant are rich in minerals

including calcium, zinc, magnesium, iron, potassium, and copper. Vitamins C, D, and E are also present, along with beta-carotene (a provitamin A), folic acid, pyridoxine, and nicotinic acid (Rh *et al*., 2019b). Mango nectar may be organically fortified with *Moringa oliefera* leaf extract to correct its nutritional inadequacies.

1.3 Justification

Mango fruit wastes contribute to greenhouse gas emissions, estimated to be around 0.46 kg CO_2/kg of mango waste, with 32% of emissions happening during transportation and the remaining 28.5% occurring as a result of pesticide utilization (Runyora, 2016). Reducing mango losses might result in a 17% increase in domestic horticultural earnings (Mujuka et al., 2020a). Developing mango nectar, on the other hand, is vital to ensuring quality and safety (Dutta et al., 2020) . Nevertheless, the nutritional value such as vitamins A and C of mango nectar is impacted by the processing technique, air, and light (Lemmens *et al*., 2013). Mango contains pro-vitamin A and vitamin C; however, pro-vitamin A and vitamin C levels in mango puree are lower, and some loss occurs during processing (Lemmens *et al*., 2013).

Moringa leaves contain greater levels of calcium, iron, potassium, and vitamins A and C than carrots, milk, spinach, or bananas. Also rumored to rival the protein quality of milk and eggs (Yessuf *et al*., 2020). Moringa may be used as a nutritional supplement (Abouel-Yazeed, 2019). As a result, adding moringa leaf extract to mango nectar enables vitamin and mineral availability enhancement and augmentation. There appears to be no published information on mango nectar blended with moringa leaf extract in Kenya. Furthermore, there is no information on the acceptability, nutritional characteristic, and self-stability of mango nectar blended with moringa leaf extract. Children, pregnant women, and persons living with HIV will benefit from this effort because they are the most vulnerable segments of society and are more likely to consume such beverages. Providing an alternative product increases the possibility of increased

mango nectar consumption and, as a result, a source of money for farmers, suppliers, processors, and distributor

1.4 Objectives

1.4.1 Overall objectives

The overall objective of the current study was to develop mineral-rich mango nectar blended with moringa leaf extract.

1.4.2 Specifics objectives

1. To ascertain the physicochemical characteristics of mango pulp and extract from moringa leaves.
2. To develop and evaluate the physicochemical properties and sensory acceptability of mango nectars blended with moringa leaf extract.
3. To determine the effect of storage on the microbiological quality and physicochemical properties of acceptable mango nectars blended with moringa leaf extract.

1.4.3 Hypotheses

1. The physical-chemical properties of mango pulp and moringa leaf extract are not different.
2. The sensory acceptability and the physicochemical characteristics of blended mango nectar are not significantly different from unblended nectars.
3. There are no changes in the microbiology quality, sensory acceptability, and physicochemical characteristics in the blended mango nectar and unblended mango nectar during storage.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

A tropical, subtropical, and frost-resistant fruit, the mango (Mangifera indica), belongs to the Anacardiaceae family (Bally & De Faveri, 2021). The term "mango" also refers to the fruit of mango trees, the Mangifera indica variety, which produces the most economically significant fruit harvest (Dutta et al., 2020). In addition to M. indica, up to 15 additional Mangifera species also yield edible fruit, such as the wild forest mango M. sylvatica and the water mango M. laurina, which is regarded to be the progenitor of Mangifera(Dutta et al., 2020).

The tree is a deeply rooted, evergreen shrub with the potential to become a massive tree, especially in areas with rich soil. Under favorable climatic circumstances, trees are upright and grow rapidly, and their canopies can be either broad or rounded. Typically, grafted trees are half the size of seedlings and can attain heights of over 20 meters (Dutta et al., 2020).Young leaves are frequently bright green or crimson and are pretty long and thin, with sharp points, oblong or lanceolate shapes, with a standard length of more than 30 cm and a maximum width of 13 cm (Warschefsky and Wettberg, 2019)

Depending on the variety, mango fruits might have smooth and soft skin and be shaped like an oval, egg, or spherical (Latheef and Rani, 2022) . All ripe varieties have a large, flat pit in the center of brilliant orange, soft interior flesh. The fruit has a flavor that is rich, delectable, fragrant, and exquisitely balanced between sweetness and acidity. It contains a substantial amount of sugar (16–18% w/v), many acids with flavoring qualities, and antioxidants like beta-carotene (Osorio and Fernie, 2013). In mature mangoes, the main sugars are fructose, glucose, and sucrose. There are also trace levels of cellulose, hemicellulose, and pectin (Dutta et al., 2020).

Most research on mango cultivars cultivated in Kenya indicates that just five to seven kinds are typically farmed. The 'Report on the Stakeholder Workshop on the Mango Value Chain ‘by

Warschefsk and Wettberg, 2019 showed that Apple, Kent, Ngowe, Tommy Atkins, and Van Dyke were the five cultivars that the 16 farmers who took part in the Promotion of Private Sector Development in Agriculture (PSDA) project grew most frequently.

(Gitahi et al., 2016) stated that in Kenya, there are seven major mango kinds: two native types, Apple and Ngowe, and five foreign cultivars, Haden, Kent, Sensation, Tommy Atkins, and Van Dyke. Mango fruit develops between 100 to 150 days of blossoming (Gitahi et al.,2016). If the fruit is left to mature on the tree, it will have the finest flavor. For commercial viability (sugars), a dissolved solids concentration of at least 13% is necessary. Fruit that is about to ripen changes to its unique hue and starts to get soft on touch (Gitahi et al.,2016). The fruit ripens most effectively when placed on trays with the stem end downward to stop sap from spreading and to promote uniformly distributed ripening at room temperature (20–25°C) while covered with a moist towel to prevent shriveling (Musyimi et al., 2013).

2.2 Global mango production and Trade

In 2013, the global mango harvest area was about 5.41 million hectares, a nearly 52% increment over 2000 (Siddiq et al., 2017). Production of mango increased by 73 percent from 24.71 million metric tons (MMT) in 2000 to 42.66 MMT in 2013. The harvested area and production have increased since 2010 by 8.95 and 14.62%, respectively (FAO, 2015). Mangoes may be cultivated in tropical and subtropical areas under a variety of climatic conditions. Asia produced more mangoes than any other region in the globe in 2013, followed by Africa (10.50%), the Americas and the Caribbean (12.22%), and Oceania (0.11%) (FAO 2015). Despite a constant increase in mango exports, most of the crop is eaten in local markets. Only 1.65 MMT, or 3.85% of worldwide output, was exported in 2013, worth around $1.69 billion (US dollars) (FAO 2016). Between 2000 and 2013, mango exports increased by 165%, from 0.62 MMT to 1.65 MMT (Siddiq et al., 2017).

2.3 Mango Production in Kenya

Smallholder farmers make about 80% of producers and 10% of the export market in Kenya's horticulture sector, respectively (Chikez et al., 2021). One of Kenya's high-potential fruits, the mango, is grown for domestic and international markets. It can grow in various agroecological zones, from sub-humid to semi-arid (Wasilwa, 2019). According to Horticultural Crops Directorate (2017), increased customer demand for fresh markets, fruit processing, and health considerations are to blame for this rise. The market for processed mango products, according to Grand Review Research (2018), was valued at USD 16.55 billion in 2018 and is projected to expand at a Compound Annual Growth Rate (CAGR) of 6.4 percent from 2018 to 2023. The anticipated annual mango production in Kenya is 1,024,500 metric tons (Chikez et al., 2021).

In Kenya, according to HCD (2018), mango, which makes up around 21% of all exported fruits' foreign revenue, is the second-most widely grown crop after banana. According to HCD (2018), a 49,098-ha area produced 779,147 million tons of mangos in 2016, valued at KES 11.9 billion. According to Wasilwa (2019), Mangoes are grown throughout the country, with the leading regions by value being Makueni (30.4 percent), Machakos (23.2 percent), Kilifi (15.5 percent), Kwale (7.9 percent), Meru (4.5 percent), Embu (2.8 percent), Bungoma (2.1 percent), Tana River (1.8 percent), Elgeyo Marakwet (1.1 percent), Muranga (1.1 percent), Tharaka Nithi (1 percent), Kitui (1 percent), Siaya (0.9 (5 percent).Wasilwa (2019) indicates that mangoes fruits in the country are mainly grown by smallholder farmers, who account for 80% of producers, and are primarily grown for domestic and international markets. According to Restivo et al. (2018), approximately 5% of mangoes fruits harvested are sold to processing companies. Musyoka et al. (2020) reported that more than 70% of mango trees planted in the Country are Apple varieties due to rapid growth and high market demand.

According to Restivo et al. (2018), of the total produced mangoes, only 10% are exported, while the rest is consumed locally. The rest are consumed raw, an aspect that Restivo et al. (2018)

observes has led to increased waste and post-harvest losses, necessitating further value addition to reduce the wastage and post-harvest losses of mangoes. kalro.org (2018) argued that though Kenya has the capacity to expand mango production, but the quantity and quality of raw and processed mangoes are insufficient to satisfy domestic and international markets. Due to this fruit's high seasonality, kalro.org (2018) suggested that the sub-sector must deal with issues like an excess of the product during peak season, which causes significant post-harvest losses, and a shortage of product during off-peak season.

2.3.1 Post-harvest Losses and Prevention of Mango Fruit in Kenya

Reid et al. (2010) argue that poor post-harvest handling practices, physiological processes like respiration, softening, and color changes, as well as environmental factors like temperature and relative humidity are to blame for mangoes' short shelf life and extreme perishability. Timmermans et al. (2014) reported that due to these aspects, despite recent growth in production and the mango's increasing economic significance, it has become hard to realize the full potential of mangoes. Timmermans et al. (2014) also indicated that poor post-harvest handling procedures result in losing at least 40–45% of mango fruits. USAID-KAVES (2014) and Ridolfi et al. (2018) both reports that mango losses in Kenya vary from 25 to 44 % across the value chain.

In light of the need to promote food security worldwide in the face of escalating climate change, USAID-KAVES (2014). In response to these needs, there has been a growing demand for the processing of mangoes to reduce post-harvest losses. Food processing increases the demand for processing, preservation, and packaging equipment, increases shelf life and reduces post-harvest losses, provides diversity, which broadens the market, adds value, which increases opportunities for new investment and employment, and promotes local small-scale manufacturing (Musyimi, 2013b). Producing the commodities gives producers a unique and additional chance to advertise their goods and boost their profits (Musyimi, 2013a).

Numerous applications and markets are made possible by the diversity of mango fruit varietals. Mango fruits are transformed into semi-finished and/or completed goods by processing. As examples of such goods based on mango, juices, marmalade, jelly, nectar, concentrate, and wines can be mentioned. Mangoes may also be used as an ingredient in ice cream, shakes, chutney, pickles, candied pulp, toppings for salads, salad appetizers, and pickles (Owino et al., 2021). Theoretically, it is possible to expand the processing of mangoes into commodities that are valuable, have extended shelf lives, and have higher nutritious value for consumers (Owino et al., 2021). This includes blending mango pulp with other natural products with high nutritional value, which grounds the current study.

2.3.2. Interventions to reduce postharvest losses in mango

The degree of post-harvest losses in a given country and the available technology and market knowledge are closely related. Postharvest value-addition technologies can minimize losses, increasing farmers' profits. However, establishing cold chains is essential for ensuring product quality and safety (Kader, 2009). Thus, smallholder farmers' income can be significantly increased by reducing post-harvest losses through cold storage technologies like brick coolers, charcoal, and Cool BotTM cold storage. However, contemporary technology adoption is still limited, and post-harvest losses are substantial in Kenya (HCDA, 2014). By promoting awareness and offering current, practical, and efficient postharvest loss reduction technology, a project in Kenya seeks to modernize two fruit aggregation centers. The study is being directed by the University of Nairobi with assistance from the Yield Wise Initiative of the Rockefeller Foundation (Karithi, 2016). Previous global and regional horticultural postharvest project initiatives are seldom, if ever, reviewed after they are finished to see if the changes pushed through during the project increase welfare and are long-lasting (Mujuka et al., 2020b).

2.3.2.1 Measures to preserve fresh fruit quality

2.3.2.1.1 Enhanced harvest field packing techniques

Saran et al. (2012) indicated that another useful strategy for small-scale farmers was to provide shade using plastic shelters. Consequently, weight loss under typical settings was 2.5% in 4 hours, whereas weight loss under shade was 0.5% in 4 hours. Buyers that visited the farm gave a more significant price per kilogram due to superior sorting and grading and the usage of upgraded packaging.

2.3.2.1.2 Practices for low energy cool storage (zero energy cool chambers) (ZECC)

The primary benefits of this low-cost, on-farm cooling system are: For it to function, it does not need any energy or power, and the materials needed—Materials, such bamboo, sand, and bricks, are readily and inexpensively accessible. The use of cool chambers, which can also drop temperature by 10 to 15 °C and maintain high humidity of around 95%, can increase the shelf life and protect the quality of horticultural goods (Hailu and Derbew, 2015).

2.3.2.1.3 utilization of Solar Drying in Tropical and Subtropical Climates

Fruits retain their nutritional content most effectively when they are kept fresh. However, the majority of storage options need low temperatures, which are difficult to maintain throughout the supply chain, especially in poor countries (Saran et al., 2012). Wakjira. (2010), stated that more substantial percentage of locally grown fruits may be preserved by using the copious solar heat present in tropical and subtropical areas to make other food products. This is one of the low input solutions that was also asserted. One of these techniques to increase the shelf life of fruits is solar drying. Furthermore, it raises nutritional standards for food, lessens seasonal surpluses, and lowers transportation costs.

Fresh food is sufficiently moist to support microbial growth and enzyme activity since it includes up to 95 percent water (Hailu and Derbew, 2015). The goal of drying is to reduce the amount of water in the produce to a level that is insufficient for microbial growth or enzyme activity. Between 10 and 15 percent of moisture is required, depending on the commodity, as eliminating too much water might make the item brittle and susceptible to breaking (Hailu and Derbew, 2015).

According to Ofor (2010), The surplus of fresh fruits and vegetables during harvest season is frequently used for drying. Without the use of solar drying facilities, open-tray sun-drying is feasible in many parts of Ethiopia with a mostly dry environment (Ofor, 2010). Vegetables in these areas may be stored at comfortable temperatures for around 18 months since sun-drying reduced their moisture content to roughly 10%. However, under typical storage circumstances, fruits have an average shelf life of seven to 36 days (Hailu and Derbew, 2015).

2.3.2.1.4 Hot water treatment

It is vital to treat some horticultural products to prevent the spread of microorganisms during distribution and storage. Dea (2010) observed that the fresh-cut "Kent" mango slices stored at 5^{o}C did not significantly suffer from the hot water quarantine treatment (dipping in 46^{o}C water for 65 to 110 minutes, depending on cultivar and fruit size).

According to Ngarmsak (2005), washing whole "Chok Anun" mangoes for 5 minutes in warm (50°C) or cold (12°C) chlorinated (100 ppm) water significantly reduced the overall microbial populations on the skin and stem end of the mangoes. Furthermore, according to these authors, both immediately following preparation and seven days at 5^{o}C, the microbial populations on freshly cut mango slices made from unwashed fruit were significantly higher than those made from cleaned fruit.

2.3.2.1.5 Calcium Therapies for the Preservation of Stiffness

According to Hailu and Derbew. (2015) based on his research on mango, the softening and browning of freshly cut mango cubes decreased their shelf life. Mango cubes treated with distilled water (control), 0.5% $CaCl_2$, and 1% $CaCl_2$ have a shelf life of approximately 5, 7, and 9 days each at 5 degrees Celsius. In comparison to mango cubes treated with 0.5% $CaCl_2$ or water, those treated with 1% $CaCl_2$ had firmer flesh and contained more calcium (control). According to Hailu and Derbew (2015), all storage methods resulted in a loss of mango cube firmness. Mango cubes treated with 1% $CaCl_2$ had a stiffness that was noticeably higher than cubes treated with 0.5% $CaCl_2$ or water (control).

2.3.2.1.6 Use of ethylene action inhibitors

Combining waxing, low O_2, high CO_2, and ripening inhibitors occasionally prolongs storage life (Genanew, 2013). In contrast, optimal therapies for each ripening inhibitor endogenous ethylene (C_2H_4) are always problematic. Consequently, several chemical formulations have been attempted to maintain ethylene below the threshold. Ethylene absorbents, such as calcium chloride ($CaCl_2$) and potassium permanganate ($KMnO_4$), in conjunction with a regulated storage environment, offer a significant economic potential that may be out of reach for small-scale farmers (Genanew, 2013).

Hailu and Derbew (2015) also looked at the quality and shelf-life of fresh-cut pieces after treating whole "Kent" mangoes with 1-methylcyclopropene (1-MCP, 25ppm), heat (38^oC and 98% relative humidity for 12 or 24 hours), or ethanol (5 g/kg). To prevent the fresh-cut pieces from browning, they were immersed in 2% calcium ascorbate and 1% citric acid. They discovered that the 1-MCP and heat treatments lowered stiffness; however, the ethanol treatment-maintained firmness comparable to the control. Cut mangoes treated with ethanol had the finest visual quality after 12 days at 7-8^oC, but an off-taste developed. Similarly, Vilas-Boas

and Kader (2007) discovered that softening and browning were slowed when 1-MCP (0.5 or 1.0 ppm for 6 hours) was directly applied to fresh-cut 'Kent' and 'Keitt' mango slices.

2.3.2.2. Mango processing into shelf-stable products

2.3.2.2.1 Mango Pulp

According to Lebeka *et al*. (2021), pulp refers to the inner, yellow, meaty, and sweet portion of the mango. The authors indicate that any mango can easily be peeled, crushed by hand, or placed in a mixer or food processor to get the pulp (Lebeka *et al*., 2021). Reddy *et al*. (2011) indicate that mango pulp is an essential part of the mango fruit, as numerous products can be made from it, including nectar, jam, wines, lather, and juice. Mango pulp generates 60 to 75% of the final product, with 25 to 40% of the residue utilized as cow feed by locals or farms (Reddy *et al*., 2011; Athiappan *et al*., 2020). Despite being important, Ellong *et al*. (2015) found that the nutritional composition of mango pulp is influenced by the location, meteorological conditions, mango variety, and stage of fruit development. Adding further, Lebaka et al. (2021) reported that mango nutritional components and bioactive content are influenced by cultivar, agroecological conditions in the region, and fruit maturity.

Regardless, quite several authors have highlighted the elemental composition of mango pulp. For instance, Maldonado-Celis *et al*. (2019) reported that ripe mango pulp is said to have 0.8 g of protein, 1.6 g of fiber, and 15 g of carbs per 100 g of fruit. Depending on the type, stage of maturation, and other factors that affect the elemental makeup of mango pulp, 13.2 to 92.8mg of vitamin C per kilogram can be found in mango pulp. Olale *et al*. (2019) reported that the Tommy Atkins type contains 0.64 mg of beta-carotene per 100 g, 0.01 mg each of lutein and cryptoxanthin, and 0.023 mg of zeaxanthin per 100 g. Meena *et al*. (2021) reported that all B complex vitamins, except biotin, are present in the ripe mango pulp, ranging from 1.5 to 2.5 mg/100 g of fresh fruit pulp. Because the fruit has a membrane, the pulp has a lot of fiber and is better for making products than juice concentrate (Olale et al., 2019). Also, Madalageri *et al*.

(2017) discovered that Mangiferin includes both carotenoids and polyphenols, making it a rich source of antioxidants. The most common phenolic acid was gallic acid (6.9 mg/kg).

2.3.2.2.2 Mango Nectar

Schwartz *et al*. (2015) revealed that the popularity of mango fruit nectar has significantly increased recently. Schwartz et al. (2015) also indicated that the indication of varying researchers has significantly contributed to this surge of mango fruit nectar. Unlike any other juice available in the standard supermarket, fruit nectar is known to be healthier. This means that mango fruit nectar, unlike any other juice, brings numerous nutritional and health benefits to the final consumers while increasing the market value for marketers. According to the Fruit Products Order (FPO) or Food Safety and Standards Authority of India (FSSAI), nectar must include 20% fruit juice, 15% sugar, and 0.3% acidity (Tahir, 2021).

Among some fruit nectar that has become common in the market, especially in tropical regions, is mango nectar, as mangoes tend to do well in these regions. Owino et al. (2021) define Mango Nectar as a mango puree that has been sweetened and thinned out with simple syrup. Owino et al. (2021) indicated that mango nectar is made by combining 20–30°Brix mango puree with water, as well as other ingredients such as sugar, citric acid, and vitamin C. Kumar et al. (2015) showed that mango nectar could be made in three different ways: vacuum-sealed in cans; pasteurized at 100°C for three minutes in an agitated retort; or pasteurized at 80°C after filling and sealing; or pasteurized at 95°C using a plate heat exchanger.

Regardless of the processing method, generally, Owino *et al*.(2021) revealed that mango nectar often includes additional ingredients (sugar, citric acid, vitamin C), carboxymethyl cellulose as a stabilizer, and around 20–33 percent pulp. It also typically has a TSS of 15oBrix, 0.30 percent acidity as citric acid, and other components. Likewise, Ellong *et al* (2015) reported that the location, climate condition, mango variety, and stage of maturity of the fruit all impact the nutritional makeup of mango nectar. Adding further, Lebaka *et al* (2021) revealed that cultivar,

local agroecological circumstances, and fruit ripeness all have an impact on the nutritional benefits and bioactive content of mango nectar. Also, Meghwal *et al* (2017) reported that the manner of processing affects the mango nectar's overall quality. Though knowing the factors that impact the quality of mango nectars is important, Tribst *et al*. (2011) indicated that most producers, especially in developing countries, are less aware of these influences, probably due to inadequate research and low availability of data concerning this topic. Going by this author's argument, it is evident that the topic concerning mango nectars is low and demands much further research.

2.4 Changes during fruit processing: mango pulp and nectar

Sidhu (2017) studied the chemical composition of mango pulp and reported that mango heated at 80°C on a plate heat exchanger before being hot loaded into cans and pasteurized at 100°C for 30 minutes had less vitamin C than unheated mango due to their heat sensitivity. Sabk *et al*. (2021) found that adding sugar raised the TSS concentration of mango juice. According to the latter author, the treatment T1 contained lower amounts of ash and crude fiber than the other treatments. Sabk et al. (2021) investigated mango nectar treated with ozone during storage and found that it had a high pH and low titratable acidity.

Silva et al. (2022) reported that processing mango pulp decreases the fruit's functional and aromatic properties. This leads to a considerable loss of volatile and bioactive chemicals, which may reduce the acceptability of processed food among consumers. To increase shelf life and preserve its microbiological integrity, mango pulp must go through industrial processing.

2.5 Chemical characteristics of mango pulp and nectar

Lebaka et al. (2021) studied mango fruit's nutritional composition and bioactive properties, concluding that cultivars, agroecological conditions in the region, and fruit maturity influenced mango fruit's nutritional composition and bioactive properties. According to Olale et al. (2019), Tommy Atkins mango fruit had 0.64 mg of beta-carotene, 0.01 mg of lutein, 0.01 mg of

cryptoxanthin, and 0.023 mg of zeaxanthin in every 100 g. Meena et al. (2021) reported that all B complex vitamins, except for biotin, are present in the ripe mango pulp, ranging from 1.5 to 2.5 mg per 100 g of fresh fruit.

The honey-enriched mango nectar was developed and evaluated by Lakhanpal and Vaidya (2015). The results indicated that TSS, titratable acidity, ascorbic acid, total reducing sugars, carotenoids, and hydroxymethyl furfural underwent minor changes during six months of storage at room temperature and low temperatures. The effect of temperature on the retention of ascorbic acid and total carotene in pulsed electric field-treated and stored at 5^{o}C mango nectar was studied by Kumar et al. (2019), who found that the retention of ascorbic acid and total carotene was more excellent in pulsed electric field-treated samples than in untreated samples and that the stability of ascorbic acid in the sample underwent combine treatment was unaffected. Vu et al. (2022) did research on the manufacturing technique of a nutritional drink produced from mango (*Mangifera indica*) and found that the vitamin C content was 8.42 mg/100ml, the total polyphenol content was 47.54 mg GAE/100ml, and the DPPH free radical activity was 11.191%. Mango might be employed as a new ingredient in the beverage sector, and microwave pasteurization could be used to produce fruit drinks, according to the results.

2.6 Micronutrient deficiencies

The specific mention of appropriate nutrition draws attention to the urgent need to address the "hidden hunger" caused by micronutrient deficiencies, which impact both poor and rich countries, albeit in different ways (McGuire, 2015). Micronutrient deficiencies affect individuals, communities, and economies and are connected to the persistence of the poverty cycle, in which persistent burdens of exhaustion and sickness lead to an inability to work and earn wages for survival (Kei and Chan, 2018). Although caloric deficiencies have been significantly improved since 2000, micronutrient deficiencies remain prevalent and pervasive. Because silent cases of moderate deficiencies are difficult to identify and measure, symptomatic

micronutrient deficiencies are estimated to afflict two billion individuals worldwide. Micronutrient deficiencies are prevalent in African and South Asian regions, according to public health indicators such as anemia, stunting, and night blindness (Benoist et al., 2008). Iron, vitamin A, iodine, folate, zinc, and B12 deficiencies are ordinary (Kei and Chan, 2018). Micronutrient deficiency symptoms, signs, and problems are more noticeable in pregnant women and children with growth retardation (Kei and Chan, 2018). Table 1 outlines the effects of common micronutrient deficits and illustrates the need for proper micronutrient consumption for health (Mullero, 2005). Iron deficiency is associated with 2 % of the gross domestic product (GDP), while vitamin A, iodine, and iron are associated with 5 % of the total GDP (Kei and Chan, 2018; Stein and Qaim, 2007). The World Health Organization (WHO) advocates three significant ways to boost micronutrient intake: variability, supplementation, and fortification (Kei and Chan, 2018; Stein and Qaim, 2007). Health organizations employ these tactics to treat micronutrient deficits. Food shortages and the inability to vary diets to balance micronutrient intakes make low- and middle-income countries particularly vulnerable to food insecurity (Kei and Chan, 2018).

Table 2.1: Common micronutrient deficiency symptoms, affected vulnerable population groups and recommended dietary allowance (RDA)

Micronutrients Essential for the functioning of	Symptoms Indicating Moderate to Severe Deficiency		RDA (mg/d,19-50yrs)
Iodine	Thyroid hormones	Goiter Mental retardation Pregnancy complications	Pregnant women Newborns and infants Vegetarians	0.15-0.3
Iron	Hemoglobin and myoglobin	Chronic fatigue Heart failure Pica	Women of child-bearing ages Children Vegetarians	8-18
Vitamin A	Eyes and immune system	Blindness Stunted growth Frequent infections	Newborns Pregnant women Children	0.7-0.9
Folate	Amino acid synthesis	Chronic fatigue Neural tube defects Stunted growth	Pregnant and lactating women Newborns and infants People with alcoholic dependence	0.4-0.6
Zinc	Immune system and amino acid synthesis	Frequent infections Stunted growth Loss of appetite	Gastrointestinal disease patients Vegetarians Pregnant and lactating women	8-11
Vitamin B12	Amino acid synthesis	Chronic fatigue Heart failure Numbness in limbs	Elderly Pregnant and lactating women Vegetarians	0.0024

Source: (Mullero, 2005).

2.7 Moringa oleifera leaves

Moringa leaf extract, extracted from the moringa tree leaves, has been identified as one of the organic ingredients that might be blended with mango pulp to boost its nutritional value. Sharareh Hekmat (2015) noted that because of its high nutritional content, moringa has lately been used in agriculture and medicine, despite its original use in human and animal nutrition. Regarding the industry's usage of moringa in medicine, Bhupendra and Neikuozo (2015) showed that moringa is currently being utilized to treat malnutrition in children under the age of three. M. oleifera is being utilized more often as a culinary additive. Bhupendra and Neikuozo (2015) claimed that Moringa leaves offer sustenance for people and animals, seed oil is used for cooking and biofuel, and seed cake is used to purify water, expanding the number of uses for moringa. Rachmaniah et al (2019) claim that African nations such as Ghana, Nigeria, Ethiopia, East Africa, and Malawi use fresh and dried Moringa leaves. According to Moyo (2012), the high nutritional content of moringa leaf is the main factor for its widespread use. The nutritional value of moringa has been studied by a large number of writers. Numerous studies have shown that moringa oleifera leaves have a superior nutritional content when compared to other foods ingested as leaves.

According to Jongrungruangchok *et al* (2010), Protein and fiber content of moringa leaves grown in 11 different districts varied, with variances ranging from 19 to 29 percent and 16 to 44 percent, respectively. According to Teixeira et al. (2014)'s study on protein content in Brazil, fresh leaves contain the highest concentrations of carotenoids such trans-lutein (around 37 mg/100 g). According to Sharareh Hekmat (2015), moringa leaves have ten times the vitamin A content of carrots, 17 times the calcium content of milk, and 25 times the iron content of spinach. Additionally, according to Moyo (2012), antioxidant substances such ascorbic acid, flavonoids, phenolics, and carotenoids are present in moringa leaves. According to Bhupendra and Neikuozo (2015), 100g of dried leaves contains 1,120 mg of oxalic acid, 1,120 mg of

calcium, 630 mg of phosphorus, 660 mg of ascorbic acid, and 0.9 g of fiber. These studies show that moringa is very nutrient-dense, which is why it is utilized widely over the world (Bhupendra and Neikuozo, 2015).

2.7.1 Chemical characteristics of moringa oleifera leaves.

It contains all the essential nutrients necessary for both human and animal health because of its high protein, calcium (Ca), iron (Fe), and vitamin C content (Bhupendra and Neikuozo, 2015). For the nutritional needs of children, adults, and nursing mothers, moringa has a total carotenoid content of 40.139 mg/100g of fresh leaves, of which 47.8 percent (18.9 mg/100g) is beta-carotene (Seshadri, 2003). Moringa leaves have high concentrations of methionine + cysteine (43.6 g/kg protein), which are equivalent to levels seen in human, cow, and chicken eggs. Researchers looked on the chemical properties of Moringa oleifera leaves by Bhupendra and Neikuozo (2015). The analysis revealed that 100 grams of dried leaves contained 1,120 mg of oxalic acid, 1,120 mg of calcium, 630 mg of phosphorus, 28.2 mg of iron, 660 mg of ascorbic acid, and 0.9 g of fiber. Moringa oleifera leaves, according to Vanisha (2006), can cure vitamin A deficiency and other nutritional deficiencies. Nouman et al (2014a) found that the nutritional content of moringa leaves is determined by the growth season and leaf stage, according to research. Moringa oleifera leaves dried during the cold season contained more protein, vitamin A, glucosinolates, and antioxidant activity than those dried during the hot season.

2.7.2 Moringa oleifera leaf nutrition and food fortification

It has been shown that the Moringa oleifera tree's high protein, fiber, and mineral content is essential for human nutrition (Jongrungruangchok *et al*., 2010; Moyo *et al*., 2011). Studies have demonstrated time and time again that *M. oleifera* leaves contain more protein than other green vegetables. According to Jongrungruangchok *et al* (2010), In 11 separate areas, the protein and fiber content of the leaves planted varied from 19 to 29 percent and 16 to 44 percent, respectively. The maximum concentration of carotenoids, including trans-lutein (approximately

37 mg/100 g), is found in fresh leaves, according to Teixeira *et al*. (2014) and Moyo *et al*. (2011), respectively. Antioxidants are plentiful in the leaves of the Moringa oleifera plant. Moringa oleifera leaves derived from products can increase the nutritious value of foods and beverages (Table 2.2). Individuals who are vulnerable must eat enough fortified meals (Oyeyinka and Oyeyinka, 2018).

Table 2.2: Nutrient Composition of Moringa leaves (100g)

Nutrient	Leaf powder	Dry leaves	Fresh leaves	Nutrient	Leaf powder	Dry leaves	Fresh leaves
Protein(g)	27.1	29.4	6.7	Vitamin C(mg)	17.3	220	15.8
Calories (cal)	205	329	92	Vitamin E(mg)	113	448	10.8
Carbohydrate (g)	38.2	41.2	12.5	Ca(mg)	2003	2185	440
Fibre (g)	19.2	12.5	0.9	Phosphorus (mg)	204	252	70
Fat	2.3	5.2	1.7	Magnesium(mg)	368	448	42
Vitamin B1 (mg)	2.64	2.02	0.06	Iron (mg)	1236	282	0.85
Vitamin B2(mg)	20.5	21.3	0.05	Potassium (mg)	1324	259	25.36
Vitamin B3(mg)	8.2	7.6	0.8	copper (mg)	0.57	0.49	0.07
Sulfur (mg)	870	-	-				

Source : (Gopalakrishnan et al., 2016a)

2.7.3 Overcoming Technical Challenges of moringa used as a Fortification

According to Oyeyinka et al (2018), the most significant obstacles to the acceptability of moringa-fortified foods are their unpleasant, leafy flavors and stunning green colors, both of

which are derived from the plant's leaves. The author suggests three strategies to overcome obstacles to employing Moringa as a natural fortifier: concealing unfavorable sensory characteristics, isolating positive chemical components, and eliminating undesirable components.

According to Chan (2018), *moringa oleifera* pods can disguise the disagreeable taste of moringa leaves. The sweeter and palatable tastes of *moringa oleifera* pods might help disguise their less attractive flavors. Consider other foods ingested with a potential food vehicle, as they may also contribute to masking unpleasant sensory features.

2.7.4 Moringa leaves processing

Hashemi et al. (2018) showed that although moringa leaves are highly nutritious, the extract from them occasionally may reduce their nutritional content. To minimize the loss of active components, Hashemi et al. (2018) suggested that fresh Moringa oleifera leaves be collected, washed, and dried for seven days at room temperature in a shed. This is followed by the extraction of the aqueous extract using the hot-water method (decoction), where 500 mL of distilled water is used to soak 50 grams of powdered material for around 10 minutes (Hashemi et al., 2018). Before collecting the sample in a conical flask and allowing it to cool, the solution is heated and twice filtered through cheesecloth. The filtrate is then dried at 70 °C in a hot-air oven. 50 grams of powdered material were steeped in 500 cc of 100% ethanol for 24 hours to create the ethanol extract (Hashemi et al., 2018). Occasionally, the mixture is stirred. The material is collected in a conical flask after 24 hours and double-filtered using a cheesecloth. The filtrate was dried in a 45°C hot-air oven (Nkechinyere Onyekwere et al., 2014).

According to Quarcoo (2008), 100 g of freshly harvested Moringa oleifera tender leaves were used to make Moringa oleifera leaf juice. These leaves were carefully cleaned in tap water, then washed once more in a sterile solution (a solution of equal parts sodium metabisulphite and citric acid at a concentration of 5%), and then rinsed once more in treated water (heated at 100

°C and then immediately refrigerated to prevent cooking). The amount of water utilized in the extraction was calculated by doing a preliminary measurement of the water-to-leaf weight ratio for mixing. To produce the extract, the slurry was filtered through sterile cheesecloth. The juice extract was centrifuged to get a clear juice extract, and it was then pasteurized for 30 minutes at 62°C.

2.8 Effect of adding processed moringa oleifera leaves

Soni and Kumar (2021) reported that Pasta that has been enhanced with Moringa oleifera leaf powder (MLP) was shown to have increased cooking quality and sensory qualities. Handayani et al (2022b) investigated the impact of fortifying ice cream with moringa leaf powder at concentrations of 0.5, 1, 1.5, and 2 percent on customer acceptance. The findings indicated that customers preferred ice cream (5 percent creamer, 15 percent sugar, 0.5 percent CMC, and 78.5 percent milk). Moringa ice cream is more popular with consumers because of its aroma and flavor.

Thiruvengadam et al (2020) developed fruit leather supplemented with Moringa oleifera (1 g, 2.5 g, 5 g, and 7.5 g). The fruit lather enriched with 2.5g of moringa oleifera was rated the most delicious. The result showed that fruit leathers' nutritional content was boosted. It was found that enhanced fruit leather had a significant amount of calcium, which is essential for healthy bones. Ismael et al (2016) evaluated the nutrient and volatile content of sweetened whey drinks that had been mixed with MOLP at 5, 10, and 15% ratios. The results showed that adding MOLP increased the nutritional value of all combinations. Sensory examination showed that Mix T1 (5 percent MOLP) performed better than the other combinations. In order to investigate volatile compounds, gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) were employed in tandem. The findings revealed that the sweetened whey beverage included seven aldehydes, five alcohols, eleven acids, and three esters. It was discovered that the two most common volatile compounds were aldehydes and acids.

Ahmed et al. (2016) evaluated moringa and aloe vera-based nutritional beverages. The Moringa-aloe vera beverage with a 50:70 v/v ratio achieved the highest hedonic scale ratings for color, odor, flavor, mouth feel, taste, and overall acceptability, with scores of 6.5, 6.5, 7.5, 8.5, and 8.3, respectively.

2.9 Changes in microbiological, chemical, and phytochemical properties of unblended and blended fruit juice during storage

Yogurt enhanced with 1 percent of Moringa oleifera was the best due to its nutritional and physiochemical benefits. For 15 days of storage at 5oC, all treatments had lower pH, moisture, and fat levels than the control. After 15 days of storage, all treatments increased acidity, protein, and syneresis (Saeed et al., 2020).

Naa et al. in 2013, evaluated the features and storage quality of fresh *Moringa oleifera* drinks (50 percent moringa extract, 38 percent pineapple juice, and 12 percent carrot extract). The result showed that fresh *moringa oleifera* drinks had 159.14 mg of vitamin C per 100 ml, 1.02 mg of iron per 100 ml, and 2.91 grams of protein per 100 ml. Despite the worst storage conditions, 78% of vitamin C was still present eight weeks later (sunlight). There was no microbial growth regardless of how the product was stored, and it was still acceptable.

The shelf life of instant soup mixes enhanced with *moringa oleifera* leaf powder (0, 18%, 20%, 22%, and 24%) was investigated by Ansari et al. (2020). Regarding overall acceptability, instant soup made with 24 percent (MLP4) flavor, Moringa leaf powder, and other components was deemed acceptable with a hedonic score of 8.04 instead of 8.4 for the control. The results suggested that supplementation with Moringa leaf powder significantly improved nutritional qualities and contained a sufficient quantity of essential elements. The developed soup was rich in protein (13.67%), ash (9.79%), fiber (5.99%), and low in fat (4.04%) and carbs (54.88%), making it an excellent option for meeting the nutritional needs of communities. Instant soup

mixes wrapped in aluminum foil and kept at room temperature for 90 days didn't significantly change their chemical, microbial, or taste properties.

Londoño et al. (2017) investigated the physicochemical, sensory, antioxidant, and composition properties of mango (cv. Azcar) juice. The most outstanding ratings for all sensory attributes were obtained for mango juices B and D, followed by juice C. Carotenoids and flavonoids rose after eight days and reduced after thirty days of storage at 20 ° C. Physical, chemical, sensory, phenolic, and antioxidant characteristics of mango juice from the ripe mango cultivar Azucar were same after 1 and 30 days.

Shamsudin. (2020) studied freshly blended pineapple-mango juice at a temperature of 42°C for 25 days. After 25 days, pineapple-mango juice was chemically and nutritionally stable. Higher physicochemical and nutritional qualities in the 80:20 mix of pineapple and mango contained more vitamin C than R50:50.

Begam et al. (2018) developed fruit drinks comprising mango, pineapple, and orange juice. The result indicated that TSS and acidity increased slightly during storage, although vitamin C and pH gradually decreased. Storage trials were carried out at one-week intervals for up to one month. The findings indicated that all the samples were in excellent condition after one month, with just a small amount of fading color observed at the end of the storage periods. The sample that got the best score in the sensory evaluation and was liked by most people had 35% mango juice, 40% orange juice, and 25% pineapple juice.

Babarinde et al. (2019b) examined fresh mango juice's efficacy and phytochemical characteristics. After being stored for 24 days, Lippen juice had the most significant values for titratable acidity (10.230.2 mg/100 g), pH (5.270.0), and Brix (14.730.1 mg/100 g), whereas Kent juice had the lowest values (7.830.2 mg/100 g), 4.410.2 mg/100 g), and 11.830.2 mg/100 g. Saigon juice had a minor ascorbic acid (9.400.3 mg/100 ml), while Lippen juice had the most significant concentration (12.100.0 mg/100 ml). As the juice grew older, its ascorbic acid

content dropped. Tannin, phytate, and saponin were present in all samples, although their effectiveness diminished with storage.

Mkandawire et al. (2016) evaluated the shelf life of a small amount of mango juice stored at temperatures of 13 and 30 ° C. Eighty plastic bottles of processed juice were stored. Twenty bottles had sodium benzoate (0.5 mg/l) at each temperature, while the remaining twenty did not. The results showed that juices stored at 30ºC had lower pH values than juices stored at 13ºC after two weeks (3.15-2.80 with preservative, 3.60-2.6 without preservative) (4.20-3.80 with preservative, 4.15-3.70 without preservative). Statistics showed that there were differences ($P<0.05$). Juice maintained at 30ºC for six weeks without preservatives experienced a tremendous loss of vitamin C (79%) (71.43%). The juice at 13ºC suffered the most negligible loss (26.98%). Juices held at 13ºC (4.5 with preservative and 4.66 without) and 30ºC (5.02 with preservative and 7.00 without preservative) underwent considerable color changes by week 6 (4.5 with preservative and 4.66 without) ($P <0.05$). Juices stored at 30°C were evaluated "poor" in week 2 for flavor (5.66 and 6.91), "poor" for smell (5.91 and 6.25), and "nearly comparable" to fresh juice (4.25 and 6.91), respectively (5.66 and 6.91). (4.25 and 4.58). Juices held at 30oC without a preservative had the highest (2.10 x 108 CFU/ml) and lowest (1.96 x 108 CFU/ml) counts, but juices stored at 13ºC with a preservative had the lowest bacteria (2.04 x 104 CFU/ml) and yeast and mold (1.72 x 104 CFU/ml) count. Juices kept at 30°C and 13°C for 2 and 4 weeks had pleasant flavors and aromas. Vitamin C loss, sensory impairment, and microbial development are all decreased by chilling.

Moringa oleifera leaf extract's effects on the shelf life and quality of freshly sweet orange juice were evaluated by Hashemi in 2018. In terms of overall acceptability during the course of the one-month storage period, the findings demonstrate that treatments B (orange juice 70% + hibiscus extract 20% + ginger extract 10%) and D (orange juice 70% + M.O.L.E. 10% + beetroot juice 10% + ginger extract 10%) fared well. Comparing Treatment D to Control A

(Orange juice 70% + water 20% + ginger extract 10%), Treatment D showed the highest levels of total soluble solids (17.4%), pH value (3.66), ascorbic acid (83.34 mg/100ml), total phenolic contents (71.44 mg GAE/ml), and antioxidant activity (75.63%). A microbiological study revealed that adding 20% M.O.L.E (treatment C) maintained the juice for up to one month longer than the control A. All of the aforementioned data indicate that M.O.L.E. was a functional ingredient with adequate safety margins for preventing bacterial growth in pharmaceutical and food applications. It also shown antibacterial properties. The Moringa plant is now useful and accessible for making a variety of edible and desired manufactured goods.

2.10 Quality issues

All fruit juices and nectars must retain the color, aroma, and taste of the fruit from which they are taken. The fruit must retain more water than necessary after washing, steaming, or other pre-treatments to maintain its natural oils and sugars (CODEX STAN 247, 2005).

Product quality is determined by its conformance to specified standards that serve as a benchmark for the manufacturer and generally ensure user pleasure (Joselyn and Heid, 1963; Quarcoo, 2008). Appearance (visual perception using the eyes), flavor or scent (taste and smell), and kinesthetic (texture) are all aspects that influence the evaluation of product quality by physical or chemical procedures and sensory analysis utilizing panelists (Heldman, 2012). According to Wibowo et al (2015b), Intrinsic variables, such as food content, may influence the chemical reactions that occur during shelf-life or storage. The latter author also said that formulations altered some quality metrics; in other words, the addition of ascorbic acid (AA), citric acid (CA), citric acid and ascorbic acid (CA + AA), and sugars (S) may affect variations in the final product's quality criteria. Heat treatment, on the other hand, may cause nutritional and taste loss in certain thermolabile items Tribst et al. 2009).

According to Tribst et al. (2011), mango nectar that had been subjected to a high-pressure homogenization process combined with optimized heating (200 MPa + 73.5 C/10 minutes) was free of microorganisms but had lost half of its vitamin C content.

2.11 Kenya standard for nectar fruit

By definition, nectar juice is not fermented. Still, it can be fermented by adding water, sugar or syrup, sweetener, or honey to produce juice, concentrated juice, water-extracted juice, dehydrated juice, or pureed juice (©KEBS, 2016). The degree Brix level for mango juice is approximately 13.3^{o}Brix, whereas the mango nectar is made approximately with 25% v/v of mango pulp for reconstituted juice. Kenya standard bureau (KEBS, 2016) stated that the maximum pH should be 4.5. According to the Kenya standard, mango nectar should contain 13.5^{o}Brix (KEBS, 2016). Ameh et al. (2015) stated that TSS may have increased due to the conversion of insoluble pectin to soluble pectin and insoluble polysaccharides to soluble polysaccharides during juice processing.

When treating fruit pulp processing as mostly a physical extraction strategy, fruit cleaning efficacy, processing length (prevent aeration or excessive illumination), and efficient cold operations are the major aspects that must be managed for pulp quality control (observing the entire cold chain, processing, transportation, and sale to the consumer). The amount of fruit ripeness and the pattern of rainfall during the harvest season are the main variables affecting the total soluble solids content of fruit pulps. These sincere worries point to poor farming methods or harvest administration. Additionally, they are connected to low-quality raw materials and pulp dilution, a common method used by certain producers to boost the effectiveness of the pulping step (Silva et al., 2017).

Brazilian legislation specifies the following minimal criteria with regard to physicochemical testing of mango fruit pulps, such as acidity, pH, °Brix, and TTA concentration: TSS (11oBrix), pH (3.3–4.5), and TTA (0.32g citric acid/100g) are the values.

Degradation of vitamin C leads to the development of non-enzymatic browning and bitter flavor in fruit pulps, making it highly important to measure vitamin C levels in fruits. A significant indicator of food quality, vitamin C also has the property of being thermolabile. Consumers may infer that other dietary components have also been preserved when vitamin C is present in food (Özkan et al., 2004). The most significant factors influencing the breakdown of vitamin C are the method of processing, storage conditions, packaging, exposure to air, light, metallic catalysts, starting vitamin C content, and microbial load (Silva et al., 2017).

Because they allow for evaluating foodstuffs for processing conditions, storage, distribution, shelf life, and public health danger, microbiological characteristics are important aspects of food quality (Silva and Abud, 2017). According to the Kenyan standard (KEBS, 2016), there should be no more than 1,000 total cfu/g of plate count, 30 cfu/g of yeasts and molds, and no Escherichia coli.

2.11 Knowledge gap

There is quite a limited literature concerning mango nectar, moringa juices, and factors that impact the quality of juices during production. In the face of increased food insecurity, the lack of enough literature has resulted in the development of low-quality food items, inadequate addressing of quality demands in many food products within the food sector, and waste of key commodities. Further study is urgently needed in this area. Also, the literature indicated that despite mango nectar missing minerals, most notably iron, zinc, and calcium, there had been no studies to determine the shelf life of mango nectar with the addition of moringa leaf extract. There are knowledge gaps in the areas of mango nectar enrichment, phytochemical analysis of mango nectar blended with moringa leaf extract, and shelf life of mango-moringa blended nectar. This research was required as a result.

CHAPTER THREE: CHEMICAL AND PHYTOCHEMICAL COMPOSITION OF FRUIT PULP OF 'APPLE' AND 'TOMMY ATKINS' MANGO VARIETIES

3.1 ABSTRACT

Kenya faces 40-50% postharvest losses in mango supply chain due to inadequate technologies. Kenya's post-harvest loss issue can be solved by mango fruit processing, which creates shelf-stable goods including chips, pulp, nectar, and juices, lowering losses and increasing farmer revenue. Micronutrients and macronutrients can be found in mango pulp; this is proof that nectar may be produced.

In this study, the chemical and phytochemical makeup of Tommy Atkins and Apple mangoes was examined. The fruits were selected, cleaned, peeled, destoned, and pulped in a pulping machine, and their chemical, nutritional, and phytochemical properties were assessed according to the Association of Official Analytical Chemists' protocols. The majority of these factors differ statistically significantly ($p<0.05$). According to the findings, mango pulp contains total phenolics (31.468 mg for apples and 28.378 mg for Tommy Atkin GAE/100g DW), flavonoids (11.457 mg for apples and 9.427 mg for Tommy Atkin QE/100g DW), vitamin C (75.81 mg for apples and 22.69 mg for Tommy Atkin mg/100g), and vitamin a (10.12 mg for apples and 2.65 mg for Tommy Atkin mg/100g). When compared to Tommy Atkin pulp, apple mango pulp contains more phenolics, flavonoids, antioxidants, and protein: (4.85%), fiber (7.92%), calcium (48.05 mg/100g D.W), and zinc (4.42 mg/100g D.W) than Tommy Atkin mango fruit pulp protein (4.72%), fiber (7.26%), calcium (33.2mg/100g DW), and zinc (4.17 mg/100g DW), but less iron (9). Tommy and Apple mango fruit can be processed into nutritious products like nectar and juices, reducing hunger and preventing deficiencies.

3.2 INTRODUCTION

The tropical, subtropical, and frost-resistant fruit known as the mango (Mangifera indica) is a member of the Anacardiaceae family (Sennhenn et al., 2014). The fruit is a fleshy drupe that

comes in a range of shapes, hues, flavors, and fiber contents. The dimensions range from 2.5 to 30 cm, and the form might be circular, ovate-oblong, or rather long. The mature fruit is highly nutritious and can serve as an energy source (Bello et al., 2016). Only bananas rank higher in terms of tropical fruit commerce in Kenya, while mangoes are Africa's seventh-most-produced tropical fruit. In subhumid to semiarid regions of Kenya, mango is a high-potential fruit farmed for domestic and export markets (Bello et al., 2016). In 2016, mango production was 779,147 million tons and was worth KES 11.9 billion. (Bello et al., 2016).

Due to inadequate postharvest handling techniques, processing facilities, and markets in Kenya, postharvest losses in the mango fruit supply chain are estimated to be between 40 and 50 percent, which has an adverse impact on farmers' income (Maloba et al., 2017).

Due to the lack of value-added technologies, viable markets for fresh fruit, and intense competition from manufactured and imported juices, less than 1% of mango fruit is processed into value-added products in Kenya (Okoth, 2013). Mango fruit value addition may be utilized to make shelf-stable products while reducing poverty via enhanced food and nutrition security (Okoth et al., 2013).

This is made feasible by procedures that keep the quality of the fruit during harvest. The procedure involves hand harvesting, chilled transit, cleaning, cooling/refrigerated storage, drying, packing and labeling, and pulp extraction (Okoth et al., 2013). Mango processing in Kenya can decrease postharvest losses by processing the fruit into pulp that can be utilized to manufacture a range of products such as juices, jams, concentrates, nectars, powders, and mango slices (Riaz and Ahmed, 2010). Fresh fruit's edible pulp makes up 33–85% of the total weight, while the skin and seed make up 7–24% and 9–40%, respectively. Thermal processing is a common method of preserving mango pulp goods, using high temperatures (>90^{o}C) for extended periods of time to ensure microbiological safety and enzyme inactivation to lengthen shelf life (Kaushik et al., 2018).

Mango pulp contains considerable amounts of calcium, copper, iron, phosphorus, manganese, magnesium, zinc, boron (0.6-10.6 mg/kg), and selenium. The pulp is rich in bioactive substances such phenolic acids, sterols, and alkaloids in addition to organic acids like citric acid, malic acid, oxalic acid, succinic acid, and tartaric acid (Owino *et al*., 2021). For various goods, such as nectar, jam, jelly powder, fruit bars, and mango flakes, mango pulp serves as the primary raw material. But its high viscosity level and naturally pulpy qualities make it less appealing (Siva et al., 2022). Additionally, earlier studies have indicated that mango pulp is a good source of macronutrients and microminerals including calcium, iron, and zinc; however, these results need to be verified before mango pulp is used to make nectar.

Even though there has been very little scientific research on the antioxidant content of mango pulp in Kenya, this study offers the chemical, nutritional, mineralogical, and phytochemical composition of mango pulp collected in Machakos County.

3.3 MATERIALS AND METHODS

3.3.1 Study design

The study design for the present investigation was a completely randomized design carried out as a comparison of mango pulp. Two mango varieties cultivated in Kenya, Apple, and Tommy Atkin, were examined for their chemical, nutritional, and phytochemical characteristics. The mango fruits were gathered at random from farms in Machakos county between January and April 2022 based on color, size, and maturity stage.

3.3.2 Procurement of mango fruits

Apple and Tommy Atkin mangoes (273kg of each kind) were harvested when mature (firm) but not ripe or ready to eat (soft) from smallholder farmers in Machakos County. The fruit was harvested early in the morning (6 to 8 a.m.) to avoid direct sunlight and gathered under shade. The fruits were delivered in a perforated crate to the department of food science, nutrition, and

technology at the University of Nairobi. Until they were processed, apples and Tommy Atkin mangoes were stored at ambient temperature (25±1°C and 47% relative humidity).

3.3.3 Preparation of mango pulp

Mangoes from the Tommy Atkin and Apple varieties were sorted according to the color of their skins as they changed from dark red to orange and yellow accents for Tommy Atkin and from green to yellow/orange for Apple. The mangoes were then washed in continuous tap water, peeled, destoned, and pulped in a pulping machine with a 0.5 mm stainless steel screen (D.K Engineering, Kenya).The extracted pulps were then pasteurized (70°C for 10 minutes) and stored with sodium metabisulphite at 300ppm, as indicated by (FAO, 2005; Omayio et al., 2022). At 55^{o}C, pasteurized mango pulp was put into 500 ml PET plastic bottles and immediately frozen at -20oC for further use (analysis).

3.3.4 Sample collection

Approximately ten bottles of each mango pulp fruit (apple and Tommy Atkin) were frozen at -20^{0}C. As a sample, one bottle of each variety was chosen at random. The frozen sample was thawed in running water in duplicate and then utilized to evaluate its proximate, chemical, and phytochemical makeup.

3.3.5 Analytical method

3.3.5.1 Proximate composition of mango pulp

The moisture content was determined using an AOAC (2005) forced air oven drier and the AOAC (2005) Methodology 930.15. (Memmert 40500-IP20-Schhutzart, Germany). The sample was dried for three hours at 105°C on aluminum dishes after being weighed on the AR3130 KERN®PCB 3500 precision weighing scale (Balingen, Germany). The moisture content was determined as a proportion of the weight loss of the sample. The ash content was determined by weighing about 10 g of the sample into silica crucibles, then drying the sample

in an oven for two hours to remove the moisture. The sample was ashed in a muffle furnace at 550±5ºC for four hours until it turned into white or gray ash. The amount of fat was determined using solvent extraction according to AOAC (2005) method 960.39a. Approximately 1 g of the dried sample was packed into thimbles and placed in a Soxhlet extraction equipment with petroleum ether as the solvent. The fiber content was determined by adding about 25ml of H_2SO_4 2.O_4N and 1.78N of KOH to 4g of juice mixed with distilled water, according to AOAC (2005) method 960.39a. After increasing the amount to 200ml, the mixture was left to boil for 30 minutes before filtering through glass wool. The glass wool was dried in an oven for two hours to remove moisture and then placed in a muffle furnace at 550±5ºC for four hours. The fiber value was calculated by difference and expressed as mg/100g. Kjeldahl distillatory equipment was used to determine the protein according to AOA (2007). About 5ml of juice was digested for 4 hours with 10ml of concentrated H_2S0_4 subscript numerals, then distilled and titrated with 0.1N NaOH in the presence of methyl orange. The outcome was expressed as mg/100g and carried out twice. The carbohydrate content of mango pulp was calculated by difference, where CHO=100-(protein%+moisture%+fiber%+fat%+ash%) using the methods described by (Gul & Safdar, 2009). The outcome was expressed as mg/100g dry weight and carried out twice. Truck et al. (2016) determined the energy by multiplying the Atwater factors for protein, carbohydrates, and fat by 4, 4, and 9, respectively. The outcome was given in terms of kcal/100g. Duplicated values were calculated for every parameter. Except for moisture, all other characteristics were computed using the dry weight basis method (d.w)

3.3.5.2 pH and titratable acidity

The AOAC (2012) method 954.06 was used to determine the pH using a digital five easy pH-meter, model F20 (Mettle, Toledo, USA), with a few modifications. Two buffer standard acid and alkali solutions, designated 4 and 7, were used to calibrate the pH meter. The pH readings were duplicated after inserting the electrode into 50 ml samples. The titratable acidity was

determined using the AOAC (2012). In the presence of phenolphthalein, 10 milliliters of samples were diluted in 50ml of distilled water and titrated with 0.1 N NaOH. The outcome was expressed in mg of citric acid/100g sample. The analysis was carried out in duplicate.

3.3.5.3 Total soluble solid

TSS was measured using a hand-held refractometer according to the AOAC (2012) method 954.06 using a refractometer (SK106-SATO, Japan). The degree of Brix measurement was obtained immediately after a sample drop was put on the refractometer's display. The readings were done in duplicate.

3.3.5.4 Vitamin C content

The AOAC 967.2 (2005) method of converting 2,6-standardized dichlorophenolindophenol (DCPIP) solution to a colorless dye was duplicated to determine vitamin C content. Titrations with a standardized ascorbic acid solution in triplicate were used to standardize the DCPIP solution. In a 50 ml volumetric flask, 10 g of the sample was weighed and filled to volume with a 5% trichloroacetic acid (TCA) solution. Ten (10 mL) of the solution was titrated against the DCPIP solution in duplicate. The vitamin C content was expressed as mg/100g of sample dry weight.

3.3.5.5 B-Carotene (pro-vitamin A) content

Utilizing modified spectrophotometric methods as Mustapha and Babura (2009) described, provitamin (vitamin A) levels were measured. A standard curve was created using a Hitachi 2900 UV/VIS spectrophotometer (Tokyo, Japan) calibrated to 450 nm and beta-carotene standards with concentrations of 0-2.4 g/mL. A mortar and pestle were used to combine one gram of each dry sample with small amounts of acetone until a colorless residue was produced. The acetone was then evaporated at 60°C in a water bath, with 25 mL of the extract added to a flask with a circular bottom. A 25 mL volumetric flask was used to hold the evaporated material

after it had been dissolved in 1 mL of petroleum ether and eluted with pet ether. After measuring the absorbance at 450 nanometers using a standard curve created using a Hitachi 2900 UV/VIS spectrophotometer (Tokyo, Japan) against pet-ether as a blank, the provitamin A concentrations were estimated. The output from the two extractions was displayed as m/100 g of the sample's dry weight.

3.3.5.6 Minerals content

Calcium, zinc, and iron content were determined using a Buck Scientific model 210 VGP atomic absorption spectrophotometer (Fort Point, USA) per the AOA (2012) method, with minor modifications. Approximately 10g of the sample was dried in an oven for two hours before being put in a muffle furnace set at 550±5^{o}C for four hours. Then, 10 ml of HCL (20%) was used for digestion, and 50 ml of distilled water was added to the digested sample. The value was given as mg/100 g dry weight.

3.3.5.7 Determination of phytochemicals

3.3.5.7.1 Total phenolic content

The total phenolic content was determined using a modified Folin-Ciocalteu technique, as Prior et al. (2005) reported. The samples (2 mL) were centrifuged overnight after being combined with 10 mL of 80% methanol. 2.5 ml of folin was added to one (1 ml) of the mixture. Two (2ml) of a 5% w/v sodium carbonate solution were added. The resulting solution's volume was increased to a final value of 10 mL by adding distilled water. At 45°C, the mixture was incubated for 15 minutes. The absorbance was measured at 765 nm wavelength using a UV-VIS spectrophotometer (Tokyo, Japan. A standard calibration curve by obtaining readings to measure the sample total phenolics concentration. The results were expressed as Gallic acid equivalents (GAE)/100 mg dry weight.

3.3.5.7.2 Total flavonoids content

The flavonoid content was assessed using a colorimetric approach proposed by Naksuriya and Okonogi (2015). Ten (10 mL) of methanol (80%) and two (2 mL) samples were combined, stirred, and centrifuged overnight. One (1 mL) sample and 4 mL of distilled water were combined and let to stand for 15 minutes. After 15 minutes, 2 mL of NaOH (1 M), 0.3 mL of aluminum chloride ($AlCl_{3)}$ (1% w/v), and 0.3 mL of sodium nitrite ($NaNO_{2)}$ (5% w/v) were added to the mixture. The volume was then upped to 10 ml using distilled water. Absorbance was then read at 510nm using a Hitachi 2900 UV/VIS spectrophotometer (Tokyo, Japan) against a blank reagent (distilled water). The flavonoid content in the sample was calculated by projecting the standard calibration curve and expressed as mg of Quercetin equivalents per 100g of dry weight (QE mg/100g).

3.4 Data analysis

Statistical analysis was conducted using computer Stata software to analyze the proximate composition, chemicals, phytochemicals, TSS, TTA, and pH. The analysis was done using a one-way variance analysis (ANOVA) at a 0.05 significance level. To demonstrate a significant difference, the means and standard deviations were split with various superscripts along a column using Bonferroni's test.

3.5 Results and Discussion

3.5.1 Results

3.5.1.1 Proximate composition of mango pulp

Several factors, including moisture, ash, protein, fiber, fat, carbohydrate, and calorie content, determine the nutritional value of mango pulp. The results showed statistically significant ($P<0.0001$) differences among the pulp samples. The moisture content ranges from 86.26 to 85.28%; Ash content ranges from 1.45 to 1.11%; the protein content of the pulp was found to

be from 4.85 to 4.72%; while carbohydrate content was found to be from 81.35 to 82.57±0.58% for Apple and Tommy Atkin mango pulp varieties as depicted on Table 3.1.

Table 3.1: Proximate composition of Apple and Tommy Atkin mango pulp in D.W basic

Pulp/moringa	Moisture (%)	Ash (%)	Fat (%)	Fiber (%)	Protein (%)	Carbohydrates (%)	Energy (kcal/100g)
Apple	86.29±0.18^{b}	1.45±0.12^{b}	0.25±0.007^{a}	7.92± 0.07^{b}	4.85±0.04^{b}	81.35±0.05^{a}	415.80±0.67^{a}
Tommy Atkin	85.28±0.30^{a}	1.11±0.06^{a}	0.47±0.006^{b}	7.26± 0.10^{a}	4.72±0.13^{a}	82.57±0.58^{b}	415.733±0.25^{b}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Values (means± standard deviation) with different superscripts along a column are statistically different at p<5% (Bonferroni's test).

3.5.1.2 Chemical, mineral, and phytochemical content of apple and Tommy Atkin mango pulp

The chemical, mineral, and phytochemical results were statistically significant ($p<0.0001$) differences among the mango pulp sample. The mango pulp's chemical, mineral, and phytochemical content are reported in Table 3.2.

The chemical analysis revealed that pH, TTA, and TSS were 4.66, 0.31%, and 13.2^{o}Brix for apple mango pulp, and 4.42, 0.48%, and 14.1^{o}Brix for Tommy Atkin mango pulp.

Vitamin C and A content of the mango pulps are shown in Table 3.2. It was found that mango pulp among the varieties, pulps from apple mango fruit contain the highest vitamin C and A content: 75.81mg/100g and 10.12 mg/100g. In comparison, pulps from Tommy Atkin fruit presented the lowest Vitamin C and A content: 22.69 mg/100g and 2.65±0.13 mg/100g, respectively.

The elemental analysis revealed that calcium, iron, and zinc content were 48.05, 5.22, and 4.42mg/100g for apple mango pulp and 33.20, 9.36, and 4.17 mg/100g for Tommy Atkin mango pulp, as shown in Table 3.2 respectively.

The phytochemical analysis showed that the total phenolics and flavonoids content were 31.468±79.47 mg GAE/100g and 11.457±21.00mg QE/100g for Apple mango pulp, while for Tommy Atkin mango pulp were 28.378±15.61 mg GAE/100g and 9.427±10.08 mg QE/100g as shown in Table 3.2, respectively.

Table 3.2: Chemical, mineral, and phytochemical content of Apple and Tommy Atkin mango pulp

Pulp	pH	TTA (g/lactic acid)	TSS Brix	VitC(mg /100g) d.w	VitA(mg /100g) d.w	Ca(mg/100g)d.w	Iron(mg/ 100g)d.w	Zinc(mg/ 100g)d.w	Total phenol (mg/d.w GAE/100g)	Flavonoids (mg/ d.wQE/100g)
Apple	4.66±0.1 ^{b}	0.31±0.0 01^{a}	13.2±0.1 ^{b}	75.81±0. 28^{b}	10.12±0. 96^{b}	48.05±0. 24^{b}	5.22±0.1 4^{a}	4.42±0.0 7^{b}	31.468±79.47 ^{b}	11.457±21.00 ^{b}
Tommy	4.42±0.0 2^{a}	0.48±0.0 04^{b}	14.1±0^{c}	22.69±1. 13^{a}	2.65±0.1 3^{a}	33.20±1. 53^{a}	9.36±0.9 6^{b}	4.17±0.5 8^{a}	28.378±15.61 ^{a}	9.427±10.08^{a}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Values (means± standard deviation) with different superscripts along a column are statistically different at $p<0.05$ (Bonferroni's test).

3.5.2 Discussion

3.5.2.1 proximate composition

The moisture content of both mango pulp was more significant than those reported by Armel Fabrice et al. (2021) in Northern ivory cost, which reported that the moisture content of mango pulp from Amelie and Kent to be 83.34 and 77.34 %, but slightly lower than the result reported by Herath1 (2019), who found a moisture content of 94.70% in Karthakolomban variety mango pulp in Sri Lanka. However, the current result on moisture content was similar to those of Okoth et al. (2013), who reported a moisture content range from 79.96±0.045 to 86.32±0.4% for apple and Kent ripened mango in the eastern province of Kenya. The high moisture content of Apple mango pulp might make it prone to dehydration and spreading germs, which could reduce its shelf life; hence, it must be stored in appropriate circumstances. In addition, this high moisture content might be advantageous for the therapeutic use of these mangos as a diuretic (Armel et al., 2021). Therefore, mango pulp from Tommy Atkin mango fruit could have more shelf life and stability than apple mango pulp fruit varieties.

The protein content of different cultivars of mangoes showed that mango pulps collected from Peru (1.5 to 5.5 %), Java (1 to 2 %), and India (0.5 to 1 %) were low in protein compared to those found in the current study (Dar et al., 2016). The protein content of this study was in agreement with those of Ibiyem (1990), who reported that the protein content of mango pulp ranged from 3.99 to 4.96%. Moreover, the result in this study was significantly lower than those reported by Arumuga (2011), which reported that the protein content of mango pulp fruit cultivars from Ethiopia was 7.96%. According to Odio's (2020) findings, a variation in the protein content of the mangoes from four different markets ranged from 2.39±0.03 to 7.03±0.05%, similar to our findings. The high protein content in mango pulp fruits indicates that such pulp can process healthy beverages to

promote metabolism and immunity. This variance might be attributable to differences in sample sources, environmental conditions, and cultural practices (Ishu, 2013).

The fiber content of mango pulp was significantly low compared to the findings of Leguizamon-Delgado et al., 2019), who found a total fiber of 21.12±0.46% in Colombia Tommy Atkin cultivar. However, the fiber content of this finding was more remarkable than those reported by Ubwa et al. (2014), who reported that the fiber content of three Nigerian mango fruit varieties ranged from 0.84 to 1.11%.

The ash content was more significant than the findings of Bello et al. (2016), who found an ash content that ranged from 0.05 to 0.49% of five local varieties of mango pulp in Kano state, Nigeria, but lower than those findings by Dyab et al., (2016), who found an ash content of 3.25% DW of Zebra cultivar mango pulp.

The result of the fat content was in line with those reported by Akther et al. (2020), who found fat content of 0.48±0.01% in Amropali fresh mango pulp, but close to the findings of Kansci et al. (2008), who found a fat content ranged between 0.17 and 0.33 g/100 g FW. Nevertheless, the fat content revealed in this work was lower than that reported by Arumugan and Manikandan (2011), who found 1.48% crude fat in Ethiopian mango fruit pulp. The fat levels reported in this study were lower than the NAFDAC maximum limit of 0.5 g/100g for fat-free meals and the EU/WHO standard of 0.25 g/100g for fruit groups (NAFDAC,2013).

The Carbohydrate content reported in this work was lower than that reported by Bello-Pérez et al. (2007), who found that the carbohydrate content varies by mango variety and ranges from 90.1 to 93.6% DW, with a caloric supply ranging from 62 to 68 KcalThis variation might be caused by changes in the supply, soil quality, or climate.

3.5.2.2 Chemical, mineral, and phytochemical content of apple and Tommy Atkin mango pulp

The chemical, mineral, and phytochemical composition of mango pulp differed significantly ($P<0.05$) among mango fruit pulp varieties. Apple and Tommy Atkin mango pulp had a higher pH than the findings reported by Vijayanand et al. (2015), who found that Totapuri, Malika, and sindura mango pulp have varying pH values of 3.9, 4, and 4.2, respectively. This result was less than Rodrguez Pleguezuelo et al. (2012) reported for Tommy Atkins (4.9). This study, however, agrees with Minuye and Ali, (2020), who reported that the pH of four mango cultivars in Ethiopia varied from 3.86 to 4.73 apple and Tommy Atkin. Fruit pulp with the lowest pH value is preserved longer than fruit pulp with a higher pH value, indicating that the mango pulp in this research had a longer shelf life and did not need pH adjustment. Minuye and Ali (2020) found that the titratable acidity (citric acid level) of the four mango varieties varied between 3.48 and 6.40 g/L, significantly higher than our findings. Despite this, Vijayanand et al. (2015) found that four mango cultivars' titratable acidity varied from 0.27 to 0.48, consistent with our findings.

The TSS in this research was similar to those reported by Kansci et al. (2008), who found TSS ranging from 9.43 to 15.16°Brix. According to Rodriquez Pleguezuelo et al. (2012), TSS varied from 15.7 to 20.0 °Brix, which was higher than the findings of this research. Mango pulp with higher sugar content is suitable for food processing since it needs less sugar. Tommy Atkin may have an advantage due to its high TSS. This fluctuation might be attributed to genetic differences and changing environmental conditions.

Vitamin C is well-known for its antioxidant effects, protecting cells from free radicals and involvement in iron absorption (Ma et al., 2011). Rebeir (2007) reported that the vitamin C concentration of Tommy Atkin and Uba mango cultivars varied from 9.79 to 77.71 mg/100 g,

which was comparable to our findings. However, Regina et al. (2004) found that the vitamin C content of Tommy Atkin and Palmer mango fruit pulp ranged from 31.7 to 56.7 mg/100g. According to Lee and Kader (2000), vitamin C concentration varies depending on mango fruit variety and region, environment, maturation stage, and postharvest handling, which may be the case in our current study. This high content could be due to mangos' stage of maturity because the vitamin C decreases during maturity and post-harvest treatment in fruits (Lee & Kader, 2000).

The vitamin A content of apple of mango pulp was higher compared to the findings of Farina et al. (2020); Maldonado-Celis et al. (2019), which found a range of 0.854 to 1.089 mg/100 and 0.3 to 1.8 mg/100g FW, but these results were comparable to Tommy Atkin's vitamin A reported in the current study. Mango pulp variations concerning vitamin A content may be related to variety, soil, and climate.

The mineral content results indicated that the Calcium and Zinc levels in this research were lower than those reported by Ma et al. (2017) , with calcium levels ranging from 31.4±1.6 to 708.4±7.2 and zinc levels from 0.23±0.1 to 5. 3±0.9 mg/100g in five mango pulp fruits; nevertheless, Iron ranged from 0.35±0.000 to 0.61±0.1mg/100g, much lower than this study reported. This mineral is needed for bone growth, vitamin D absorption, and the creation of cellular energy (Armel et al., 2021a).

In addition to vitamin C, vitamin E, and carotenoids, phenolic compounds, known as secondary metabolites, are the primary antioxidants in plants. With its high polyphenol content, the apple variety might be advised to prevent cardiovascular illnesses (Armel et al., 2021b). The total phenolics content in the current study is low in comparison to the findings of Bm and Bhattacherjee (2019) but similar to those reported by Ma et al. (2017). Ribeiro et al. (2007) found a total phenolics content that varies across the four mango varieties, with Uba pulp having the greatest (approximately 200 mg GAE/100 g) and Tommy Atkins pulp having the lowest (50 mg GAE/100

g), which were similar to the findings of the current study. According to Palafox-Carlos et al. (2012), the phenolic content of ripe Ataulfo mango pulp was 174 mg GAE/100 g FW. The flavonoid content was consistent with the research done by Bm and Bhattacherjee (2019). According to the results, the variation in the total phenolics and flavonoid content of mango pulp may be related to the various mango pulp-producing varieties.

3.6 CONCLUSION

The Chemical, proximate, and phytochemical characteristics of the two mango cultivars varied considerably at $p < 0.05$. Apple mango pulp exhibited the highest nutritional value concerning higher protein, vitamins A and C, phenolics, and flavonoid content than Tommy Atkin mango pulp. Mango pulp in both varieties may be utilized as a source of functional nutrients and natural antioxidants in the food industry.

CHAPTER FOUR: ACCEPTABILITY AND CHEMICAL PROPERTIES OF MANGO NECTAR ENRICHED WITH MORINGA (*MORINGA OLEIFERA*, LAM) LEAVES EXTRACT

4.1 ABSTRACT

Mango and Moringa are nutrient-dense foods. This study explores mango varieties for nectar production enriched with Moringa leaf extract to reduce postharvest losses and malnutrition in Kenya. Mango loss affects farmers' income and the environment. Mango fruit processed into mango nectar can address PHL (postharvest losses) solution. Mango nectar is rich in vitamins and minerals but contains insufficient micronutrients. Moringa leaf are nutrient-rich. Adding moringa leaf extract to mango nectar improves its nutrition. The developed product contained 25% mango pulp and aqueous solutions of moringa leaf extract (F1, F2, F3, F4, F5, F6, F7, and F8): 0%, 10%, 12.5%, and 15%, respectively. The produced nectar was pasteurized at 70°C for 10 min. The developed nectar was analyzed for sensory evaluation, proximate composition, vitamin A, and mineral content. F1 (control) and F3 (apple manga nectar blended with 12.5% moringa leaf extract), and F5 and F6 (Tommy Atkin mango nectar blended with 10% moringa leaf extract) were accepted. The analysis was carried out on the most acceptable product. The formulated nectar differed in protein, fiber, ash, carbohydrate, energy, vitamin A, mineral content and sensory acceptability ($p<0.05$), except for moisture and fat. Apple blended mango nectar had more fat, vitamin A, calcium, iron, and zinc than Tommy Atkin blended nectar: 1.07 and 0.60%, 8.68 and 6.91mg/100g, 39.89 and 34.26 mg/100g, 3.14 and 2.01mg/100g, and 8.85 and 7.19mg/100g. However, Tommy blended nectar had more fiber, protein, and energy. Therefore, moringa leaf extract can be used to fortify food and beverages.

4.2 INTRODUCTION

Seasonal gluts and high post-harvest losses are the two most serious issues that make it difficult for developing countries to get fruits and vegetables all year (Jolayemi and Adeyeye, 2018). Mango is a climacteric fruit with several varieties, although only a few are significant economically and commercially (Wibowo et., 2015a). Due to a lack of value-added technology, viable fruit markets, and competition from manufactured and imported juices, less than 1% of mango fruit is processed into value-added products, according to Okoth (2013). It is currently ordinary practice to process fresh fruit into dried fruits, "pulps or purees," "nectars," and "clarified" or "unclarified" beverages to reduce postharvest loss and make it easily accessible during the off-season (Lozano, 2006 and Babarinde et al., 2019c). Agronomical (variety/cultivar, maturity, ripeness) and technological (time-temperature combination, packaging, storage) aspects influence fruit quality (Arah et al., 2015; Rouphael, 2012). Mango products are rich in vitamins (Vit C, provitamin A, and B complex) and minerals (potassium and manganese) but deficient in calcium, iron, zinc, and antioxidants (Lebaka et al., 2021). Mango fruit value addition might reduce postharvest losses and relieve poverty by improving food and nutrition security in Kenya (Okoth et al., 2013). Mango nectar's nutritional value is significantly affected by processing techniques, air, and light (Jolayemi, 2019; Lemmens et al., 2013).

Moringa oleifera, a member of the Moringaceae family, is now grown in tropical and subtropical climates. *M. oleifera* has many nutritional and physiological attributes (Qadir et al., 2022). Physicochemical analyses have shown that *M. oleifera* leaves provide an abundant source of iron, phosphorus, calcium, potassium, essential amino acids, vitamin D, and anti-cancer compounds, including phenolics, flavonoids, vitamin C, and β-carotene (Abdull Razis, 2014). Additionally, Moringa leaves are an excellent source of provitamin A, proteins, minerals, and antioxidants (Anwar et al., 2007).

Given its nutritional benefits, moringa oleifera leaves may also be used to fortify other products such as sauces, juices, milk, and bread (Jones et al., 2007). *M. oleifera* is the most valuable component and is utilized for nutritional and medicinal purposes (Nouman et al., 2016). Since there is no scientific research on the nutritional composition of mango nectar blended with moringa leaf extract in Kenya, the present study determines the acceptability of mango nectar supplemented with moringa leaf extract and its nutritional qualities.

4.3 MATERIALS AND METHODS

4.3.1 Procurement of fruits, Moringa leaves, and Additives

Apple and Tommy Atkin mangoes (273kg of each kind) were harvested when mature (firm) but not ripe or ready to eat (soft) from smallholder farmers in Machakos County. The fruit was harvested early in the morning (6 to 8 a.m.) to avoid direct sunlight and was gathered under shade. The fruit was transported in crates to the University of Nairobi's College of Agriculture, food science, nutrition, and technology department. For ripeness, mango fruits were stored at room temperature (25±2^{o}C, 47 % relative humidity). Moringa leaves were obtained from smallholder farmers in Kajiado county, Kenya. The leaves were packed in a cleaned sac and carried in vehicles for around 1h 30 minutes before being sprayed on the stainless-steel table to remove heat, minimize nutritional loss, and off-flavor of the final product. Sugar, citric acid, stabilizer, and preservative were purchased from Pradip Kenya in Nairobi. The chemicals used in this study were of laboratory grade. All materials were processed in the food science, nutrition, and technology department's food processing center and pilot plant.

4.3.2 Preparation of mango pulp

Apple and Tommy Atkin mangoes were sorted based on the color of their skins as they turned green to yellow/orange for Apple, dark red to orange and yellow accents for Tommy Atkin, and washed in continuous tap water before being weighed, peeled, destoned, and pulped in a pulping machine equipped with a 0.5 mm stainless steel screen (D.K Engineering, Kenya). The extracted pulps were subsequently pasteurized (70°C for 10 minutes) and preserved with sodium metabisulphite at 300 ppm, as recommended (FAO, 2005; Omayio et al., 2022). The pasteurized mango pulp was hot filled into 5 L PET plastic bottles at 55^{o}C and then stored at room temperature (25±2^{o}C with a relative humidity of 47%) for further treatment.

4.3.3 Preparation of moringa leaf extract

Fresh *moringa oleifera* leaves (46 kg) were stripped off from their branches, cleaned with running water, chopped into small pieces, and blanched for 3 minutes at 90 °C. The blanched leaves were immersed in chilled waters (10±2^{o}C) water for 3 minutes to avoid further cooking, then crushed using a chopping box with 200ml of water per 100g of blanched moringa leaf. The extract was recovered using a hydraulic press. The extract was filtered with a 4-layer muslin cloth to remove pomace and then frozen at -20^{o}C for further use (Naa et al., 2013; Rh et al., 2019b).

4.3.4 Preparation of blended mango-moringa nectar

Blended mango-moringa nectar was made with 25% mango pulp and 0, 10, 12.5, and 15% of moringa leaf extract, water, sugar, citric acid, carboxymethyl cellulose (CMC), and potassium metabisulphite were added to finalize the preparation following Kenyan standards (©KEBS, 2016). The control contained 25% mango (from apple and Tommy Atkin) pulp and other ingredients, as detailed in Table 4.1. According to the flow chart (Figure 4.1), mango nectar blended with moringa leaf extract was pasteurized at 70°C for 10 minutes before being filled hot at 55°C in 500ml.

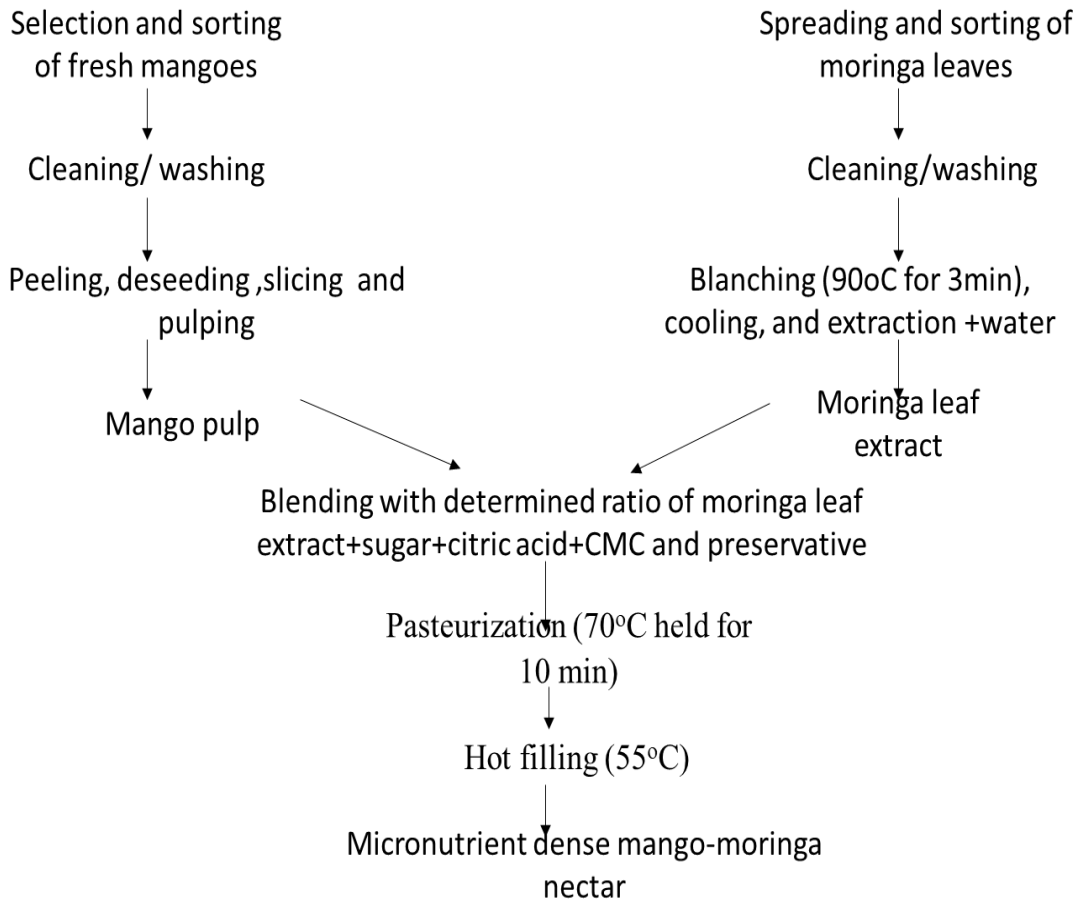

Figure 4.1: Flow diagram of mango-moringa blended nectar.

Table 4.1: Different formulations of mango-moringa nectar

Treatment	The portion of ingredients (%)							
Formulations	**Pulp**	**Moringa leaf extract**	**Water**	**Sugar**	**Citric Acid**	**Stabilizer**	**Preservative**	**Product Name**
1	25	0	64.73	10	0.1	0.15	0.02	Control
2	25	10	54.73	10	0.1	0.15	0.02	M-mn
3	25	12.5	52.23	10	0.1	0.15	0.02	M-mn
4	25	15	49.73	10	0.1	0.15	0.02	M-mn

The mango-moringa nectar component is a 100% mixture design of developed products for both mango varieties, with M-mn (mango-moringa nectar).

4.3.5 Sensory Evaluation of Mango-moringa nectar

Untrained panelists (30) of both genders assessed mango-moringa nectar samples based on appearance, odor, taste, texture, mouth feel, and overall acceptability. Panelists were instructed to use a seven-point hedonic scale to record their observations on the sensory sheet (7 and 1 points showing they like it extremely and dislike it extremely, respectively). The sensory evaluation took place in a well-lit sensory room, with palates rinsed using filtered water before and after each formulation being tested. The most popular preferred formulations were subjected to proximate and chemical analysis.

4.3.6 Assessments of chemical properties of mango-moringa blended nectar

4.3.6.1 Proximate composition

AOAC (2005) Method 930.15 and a forced air oven dryer were used to determine the moisture content (Memmert 40500-IP20-Schhutzart, Germany). The sample was weighed on the AR3130 KERN®PCB 3500

precision weighing scale and then dried for three hours at 105°C on metal dishes (Balingen, Germany). The moisture content was calculated as a percentage of the sample's weight loss. Weighing around 10 g of the sample into silica crucibles, then removing the moisture by drying the sample in an oven for two hours, allowed us to calculate the ash content. The sample was heated to between 550 ±5^{o}C in a muffle furnace for four hours, causing it to become white or gray ash. According to AOAC (2005) method 960.39a, solvent extraction was used to calculate the amount of fat. A Soxhlet extraction apparatus was used to extract the sample, which weighed around 1 g, using petroleum ether as the solvent.

The fiber content was determined by adding about 25ml of H_2SO_4 2.O4N and 1.78N of KOH to 4g of juice mixed with distilled water, according to AOAC (2005) method 960.39a. After increasing the amount to 200ml, the mixture was left to boil for 30 minutes before filtering through glass wool. The glass wool was dried in an oven for two hours to remove moisture and then placed in a muffle furnace set at 550±5^{o}C for four hours. The fiber value was calculated by difference and expressed as mg/100g. Kjeldahl distillatory equipment was used to determine the protein per AOAC (2007) method 924.63. About 5ml of juice was digested for 4 hours with 10ml of concentrated H_2S0_4 subscript numerals, then distilled and titrated with 0.1N NaOH in the presence of methyl orange. The outcome was noted twice and given as mg/100g.

The carbohydrate content of mango pulp was calculated by difference, where CHO=100-(protein%+moisture%+fiber%+fat%+ash%) using the methods described by (Gul and Safdar, 2009). The outcome was expressed as mg/100g dry weight and carried out twice. Truck et al. (2016) determined the energy by multiplying the Atwater factors for protein, carbohydrates, and fat by 4, 4, and 9, respectively. The outcome was given in terms of kcal/100g. Duplicated values were calculated for every parameter. Except for moisture, all other characteristics were computed using the dry weight basis method (d.w).

4.3.6.2 pH and titratable acidity

The AOA (2012) method 954.06 was used to determine the pH using a digital five easy pH meter, model F20 (Mettle, Toledo, USA), with a few modifications. Two buffer standard acid and alkali solutions, designated

4 and 7, were used to calibrate the pH meter. The pH readings were duplicated after inserting the electrode into 50 ml samples. The titratable acidity was determined using the AOAC (2012) method 954.06. In the presence of phenolphthalein, 10 milliliters of samples were diluted in 50ml of distilled water and titrated with 0.1 N NaOH. The outcome was expressed in mg of citric acid/100g sample. The analysis was carried out in duplicate.

4.3.6.3 Total soluble solid

TSS was measured using a hand-held refractometer according to the AOAC (2012) method 954.06 using a refractometer (SK106-SATO, Japan). The degree of Brix measurement was obtained immediately after a sample drop was put on the refractometer's display. The readings were done in duplicate.

4.3.6.4 B-carotene (pro-vitamin A) content

Utilizing modified spectrophotometric methods as Mustapha and Babura (2009) described, provitamin (vitamin A) levels were measured. Using beta-carotene standards with concentrations ranging from 0-2.4 g/mL and a Hitachi 2900 UV/VIS spectrophotometer (Tokyo, Japan) calibrated to 450 nm, a standard curve was produced. A mortar and pestle were used to combine one gram of each dry sample with small amounts of acetone until a colorless residue was produced. The acetone was then evaporated at 60°C in a water bath, with 25 mL of the extract added to a flask with a circular bottom. A 25 mL volumetric flask was used to hold the evaporated material after it had been dissolved in 1 mL of petroleum ether and eluted with pet ether. The provitamin A concentrations were calculated by measuring the absorbance at 450 nanometers using a standard curve made using a Hitachi 2900 UV/VIS spectrophotometer (Tokyo, Japan) against pet-ether as a blank. The results of the two extractions were shown as mg per 100 g of the dry weight of the sample.

4.3.6.5 Minerals content

Calcium, zinc, and iron content were determined using a Buck Scientific model 210 VGP atomic absorption spectrophotometer (Fort Point, USA) per the AOA (2012) method 954.06, with minor modifications. Approximately 10g of the sample was dried in an oven for two hours before being put in a muffle furnace set

at 550±5^{o}C for four hours. Then, 10 ml of HCL (20%) was used for digestion, and 50 ml of distilled water was added to the digested sample. The value was given as mg/100 g dry weight.

4.3.4 Data analysis

The sensory, proximate composition, and physicochemical data were entered into Microsoft Excel (2015). Sensory analysis packages in XLSTAT for Excel (Addinsoft, 2021; Vidal, 2020) were used for product characterization, panel analysis, sensory profiling, and statistical analysis. The proximate and chemical data were evaluated in Stata software using one-way ANOVA. The means and standard deviations were split with various superscripts along a column using Bonferroni's test to determine if there is significant differences or not.

4.4 Results

4.4.1 Proximate composition of Moringa leaf extract

The proximate analysis of Moringa oleifera leaf extract (F.M.O.L.E) (Fig 4.2). Moisture, ash, fat, fiber, protein, carbohydrates, and energy were statistically significant ($p<0.0001$) different: 97.22±0.09% moisture, 9.68±0.13% ash, 0.79±0.01% fat, 10.54±0.47% crude fiber, 21.09±1.01% crude protein, 56.95±0.56% carbohydrates, and 321.51±1.06 kcal/100g d.w.

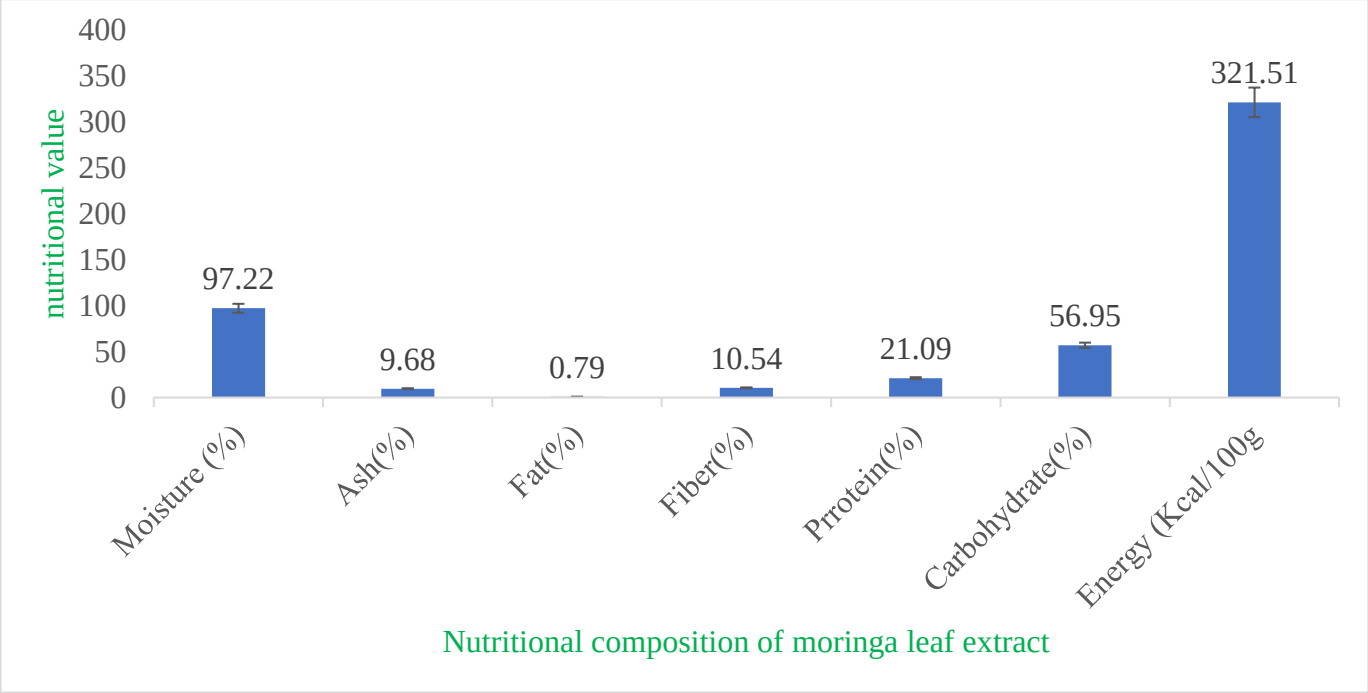

Figure 4.2: Nutritional composition of moringa leaf extract

4.4.2 Chemical and minerals content of moringa leaf extract

The mineral and chemical content of moringa leaf extract was significant ($p<0.0001$) differences as shown in Fig 4.3: pH (5.91±0.04), TTA (0.18±0.004), TSS (3.07±0.06%), Vit A(11.42±0.84mg/100gdw), calcium(910.18±15.90mg/100gdw), Iron (90.26±1.80mg/100g dw) and Zinc(28.88±1.25mg/100gdw).

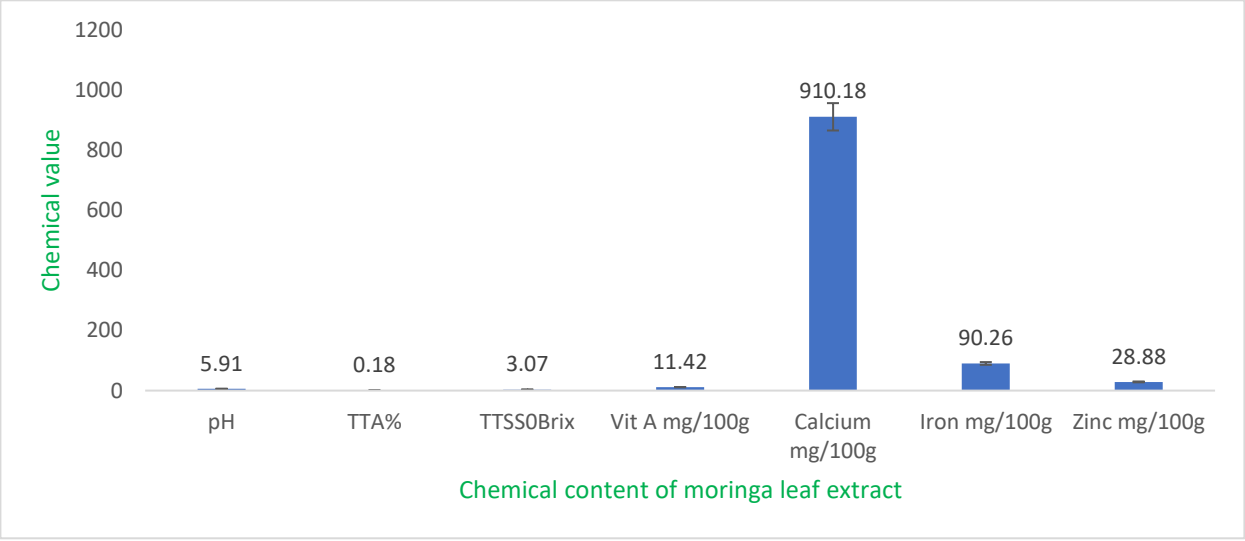

Figure 4.3: Chemical characteristic of moringa leaf extract

4.4.3 Sensory evaluation of mango nectar enriched with moringa leaf extract

For unblended and blended mango-moringa nectar, the sensory data shown in Table 4.2 showed significant ($P<0.05$) variations in color, odor, taste, texture, mouth feel, and overall acceptability between the samples. Unblended mango (from Apple and Tommy Atkin) nectar had high mean score than mango nectar blended with moringa leaf extract. An increase in the amount of moringa leaf extract generally resulted in lower scores for each sensory parameter. Unblended Apple mango nectar's color, odor, taste, texture, mouthfeel, and overall acceptability were rated 6.73±0.57, 6.09±1.18, 6.12±1.22, 5.82±1.42, 5.82±1.74 and 6.27±0.94, while Apple mango nectar blended with 12.5% M.L.E were rated 4.48±1.60, 3.45±1.64, 4.52±1.56, 5.06±1.52, 4.64±1.69 and overall acceptability 4.73±1.38, respectively. Tommy Atkin mango nectar control color, odor, taste, texture, mouthfeel, and overall acceptability were rated 6.27±0.94, 6.15±1.06, 5.88±1.41, 5.79±1.27, 5.58±1.48, and 6.06±0.83 while Tommy Atkin mango nectar blended with 10% MLE were 3.21±1.65, 3.30±1.63, 4.38±1.77, 4.64±1.73, 4.82±1.67, and 4.30±1.57, respectively. Among the eight formulations, four formulations were the most preferred by all panelists, such as F3 (Apple mango nectar enriched with 12.5% moringa leaf extract) and F6 (Tommy Atkin mango nectar supplemented with 10% moringa leaf extract) alongside the control F1 (Apple mango nectar) and F5 (Tommy Atkin mango nectar).

Table 4.2: Sensory scores for the formulated mango-moringa blended nectar

Product	Sensory attributes					
	Color	Odor	Taste	Texture	Mouth feel	Overall acceptability
F1	6.73±0.57 ^{c}	6.09±1.18 ^{b}	6.12±1.22 ^{b}	5.82±1.42 ^{b}	5.82±1.74 ^{c}	**6.27±0.94 ^{b}**
F2	4.48±1.48 ^{b}	3.12±1.60 ^{a}	4.06±1.80 ^{a}	4.58±1.75 ^{a}	4.61±1.77 ^{abc}	4.30±1.53 ^{a}
F3	4.48±1.60 ^{b}	3.45±1.64 ^{a}	4.52±1.56 ^{a}	5.06±1.52 ^{ab}	4.64±1.69 ^{abc}	**4.73±1.38^{a}**
F4	3.82±1.61 ^{ab}	3.55±1.79 ^{a}	4.12±1.69 ^{a}	4.82±1.33 ^{ab}	4.36±1.82 ^{ab}	4.33±1.57 ^{a}
F5	6.27±0.94 ^{c}	6.15±1.06 ^{b}	5.88±1.41 ^{b}	5.79±1.27 ^{b}	5.58±1.48 ^{bc}	**6.06±0.83 ^{b}**

F6	3.21±1.65 [a]	3.30±1.63 [a]	4.38±1.77 [a]	4.64±1.73 [a]	4.82±1.67 [abc]	**4.30±1.57 [a]**
F7	3.64±1.80 [ab]	3.45±1.79 [a]	4.21±1.63 [a]	4.18±1.59 [a]	4.09±1.91 [a]	4.21±1.54 [a]
F8	3.24±1.90 [a]	3.21±1.93 [a]	4.15±1.91 [a]	4.67±1.65 [a]	4.39±1.71 [ab]	4.03±1.69 [a]
p-value	<0.0001	<0.0001	<0.0001	<0.0001	0.000	<0.0001

Values (means± standard deviation) with different superscripts along a column are statistically different (Turkey's test). Where: F1: Apple mango nectar control; F2 (Apple mango nectar enriched with 10% moringa leaf extract); F3 (Apple mango nectar enriched with 12.5% moringa leaf extract); F4 (Apple mango nectar enriched with 15% moringa leaf extract). F5: Tommy Atkin mango nectar control; F6 (Tommy Atkin mango nectar contains 10% moringa leaf extract; F7 (Tommy Atkin mango nectar contains 12.5% moringa leaf extract, and F8 (Tommy Atkin mango nectar contains 15% moringa leaf extract.

4.4.4 Proximate composition of mango nectar blended with moringa leaf extract

The moisture, ash, protein, fiber, fat, carbohydrate, and energy content of unblended and blended mango nectar are presented in Tables 4.3 and 4. There was no significant variation in moisture for Tommy Atkin mango nectar and fat content for Apple mango nectar ($p>0.05$). However, there were significant differences ($p<0.05$) in the ash, fat, fiber, protein, carbohydrate, and calories. The addition of 10% moringa leaf extract to Tommy Atkin mango nectar increased the ash from1.16±0.06% to 1.41±0.09%, fat from 0.44±0.04% to 0.60±0.04%, fiber from 3.47±0.04% to 3.81±0.02%, protein from 2.48±0.08% to 4.13±0.02% and energy from 413.20±1.87 kcal/100g to 424.98±1.78 kcal/100g content while decreasing the moisture from 87.39±0.20% to 87.26±0.07% and carbohydrate from 90.96±0.50% to 89.01±0.54% content. The addition of 12.5% moringa leaf extract to Apple mango nectar caused a modest decrease in moisture from 87.59±0.41% to 86.45±0.25% and carbohydrate from 94.18±0.07% to 93.63±0.18% content while increasing ash from 1.43±0.11% to 1.66±0.08%, fat from 1.05±0.04% to 1.07±0.06% fiber from 3.29±0.1% to 3.57±0.05%, protein from1.85±0.06% to 2.68±0.09%, and energy from 392.86±0.65kcal/100g to 394.66±0.91kcal/100g content.

Table 4.3: Proximate composition of unblended and blended apple mango nectar

Product	Moisture (%)	Ash (%)D.W	Fat (%)D.W	Fiber (%)D.W	Protein (%)D.W	Carbohydrates (%)D.W	Energy (Kcal/100g) D.W
F1	87.59±0.41[b]	1.43±0.11[a]	1.05±0.04[a]	3.29±0.1[a]	1.85±0.06[a]	94.18±0.07[b]	392.86±0.65[a]
F3	86.45±0.25[a]	1.66±0.08[b]	1.07±0.06[b]	3.57±0.05[b]	2.68±0.09[b]	93.63±0.18[a]	394.66±0.91[b]
T-statistic	3.7472	-15.6003	-0.6047	-8.7104	-32.1098	8.4274	-3.4100
P-value	0.0322	0.0020	0.3034	0.0065	0.0005	0.0069	0.0381

Values (means± standard deviation) with different superscripts along a column are statistically different at $p<0.05$ (Bonferroni's test).

Where: F1: Apple mango nectar (0% moringa leaf extract) and F3: Apple mango nectar blended with 12.5%moringa leaf extract

Table 4.4: Proximate composition of unblended and blended Tommy Atkin mango nectar in D.W except moisture

Product	Moisture (%)	Ash (%)	Fat (%)	Fiber (%)	Protein (%)	Carbohydrates (%)	Energy (Kcal/100g)
F5	87.39±0.20^{a}	1.16±0.06^{b}	0.44±0.04^{a}	3.47±0.04^{a}	2.48±0.08^{a}	90.96±0.50^{b}	413.20±1.87^{a}
F6	87.26±0.07^{a}	1.41±0.09^{a}	0.60±0.04^{b}	3.81±0.02^{b}	4.13±0.02^{b}	89.01±0.54^{a}	424.98±1.78^{b}
T-statistic	0.8759	-2.9971	-3.2435	-10.7973	-27.9022	3.2730	-5.6086
P-value	0.7633	0.0478	0.0417	0.0042	0.0006	0.0410	0.0152

Values (means ± standard deviation) with different superscript letters along the columns are significantly different at $p<0.05$ (Bonferroni's test). Where: F5: Tommy Atkin mango nectar control (with 0% moringa leaf extract) and F6: Tommy Atkin mango nectar blended with 10%moringa leaf extract.

4.4.5 Vitamin A and mineral content of mango nectar blended with moringa leaf extract

According to Tables 4.5 and 6, mango nectar blended with 10 and 12.5 % moringa leaf extract had significantly more vitamin A, calcium, iron, and zinc than unblended mango nectar, for both Apple and Tommy Atkin mango varieties.

Unblended and blended mango nectar were significantly different ($p<0.05$), with Apple mango nectar blended with 12.5% MLE containing more vitamin A (8.68mg/100g), calcium (39.89 mg/100g), iron (3.14 mg/100g), and zinc (8.85 mg/100g) than Tommy Atkin mango nectar blended 10% MLE, which contained 1.87 mg/100g, 34.26 mg/100g, 2.01 mg/100g, and 7.19 mg/100g D.W for Vit A, calcium, iron, and zinc, respectively.

Table 4.4: Vitamin and mineral content of Apple Mango Nectar enriched with 12.5% M.L.E(mg/100g D.W)

product	Vitamin A	Calcium	Iron	Zinc
F1	6.91 ± 0.25^{a}	20.51 ± 0.86^{a}	0.70 ± 0.05^{a}	8.31 ± 0.38^{a}
F3	8.68 ± 1.07^{b}	39.89 ± 1.51^{b}	3.14 ± 0.15^{b}	8.85 ± 0.27^{a}
T statistic	-3.3117	-14.8591	-30.5425	-2.2141
P-value	0.0402	0.0022	0.0005	0.0786

Values (means ± standard deviation) with different superscript letters along the columns are significantly different at $p<0.05$ (Bonferroni's test). Where: F1: Apple mango nectar control (with 0% moringa leaf extract) and F3: Apple mango nectar blended with 12.5%moringa leaf extract

Table 4.5: Vitamin and mineral content of Tommy Atkin Mango Nectar blended with 10% M.L.E (mg/100g D.W)

product	Vitamin A	Calcium	Iron	Zinc
F5	1.44 ± 0.09^{a}	22.72 ± 0.84^{a}	0.93 ± 0.03^{a}	6.79 ± 0.10^{a}
F6	1.87 ± 0.05^{b}	34.26 ± 0.79^{b}	2.01 ± 0.02^{b}	7.19 ± 0.19^{b}
T statistic	-18.0278	-22.9488	-54.0494	-4.8813
P-value	0.0015	0.0009	0.0002	0.0197

Values (means ± standard deviation) with different superscript letters along the columns are significantly different at $p<0.05$ (Bonferroni's test). Where: F5: Tommy Atkin mango nectar control (with 0% moringa leaf extract) and
F6: Tommy Atkin mango nectar blended with 10%moringa leaf extract.

4.5 Discussion

4.5.1 Proximate composition of moringa leaf extract

The moisture content of moringa leaf extract was consistent with those of Obiajul (2020), who found 97.580% moisture content for unboiled moringa leaf extract. However, the moisture level of the current study was higher than that of Fombang and Mbofung (2017), who found a moisture content of 79.9% for fresh moringa leaves and 77.9% for blanched moringa leaves. The high moisture content detected in this study's moringa leaf extracts may be a consequence of the extraction technique (aqueous extraction). Obiajulu (2020) reported a fat content of 0.0835% for moringa Leaf Extract, which was comparable to the fat content observed in the current investigation. Sunday et al. (2016) reported similar results on fresh Curcuma longa extract. Since *moringa oleifera* supplies essential oil, the extract's fat content is beneficial. The ash and fiber values were comparable to those reported by Fombang and Mbofung (2017), who reported ash and fiber contents of 8.4 and 7.7% for blanched moringa leaves and 9.5 and 8.2% for fresh moringa leaves, respectively. However, this study's ash and fiber contents were much higher than those of Obiajulu (2020), who found an ash content ranging from 0.485 to 1.455% and 0% fiber in an unboiled moringa leaf extract. According to (Moyo et al., 2011), *moringa oleifera* leaves contain 33.3% crude protein, making it an essential crop for combating malnutrition. These findings supported the outcomes of the present research.

However, the present study's protein content was higher than that reported by Onyekwere (2014) and Obiajulu (2020), who found 18.92% and 0.630% crude protein content in moringa leaf extract, respectively. This study's carbohydrate content was consistent with Onyekwer's (20 findings, who found 57.01% carbohydrate content in the moringa leaf extract. Agricultural locations, growing conditions, soil type, seasonal fluctuations, distinct genetic cultivars, processing technologies, and analytical time might cause variations in nutritional values of moringa leaf extract. Similar findings were reported by Jongrungruangchok et al. (2010), who observed a slight variation in the proximate composition contents of the eleven distinct samples of moringa leaves and those of previously published research.

4.5.2 Chemical and minerals of moringa leaf extract

The moringa leaf extract pH, as shown in this investigation, was somewhat higher than the pH reported by Shah et al. (2015), who found a pH ranged from 5.45 to 5.6, despite Noaman et al. (2022) reporting high levels of pH (6.86). The TTA findings were consistent with studies by Rh et al. (2019), who found that moringa leaf extract has a TTA of 0.11% and a higher TSS value than the current study. However, the TSS and TTA of moringa leaf extract were marginally lower than those reported by Noaman et al. (2022), who found a TSS of 4^{o}Brix and TTA of 0.66%, respectively.

The vitamin A content of moringa leaf extract was comparable to that reported by Obiajulu (2020), who found 10,346 mg/100g in moringa leaf extract boiled for 15 minutes, but significantly higher than that found by Naa et al. (2013), reported 5.98 mg/100g.

Compared to our findings the mineral content of the previous study done by Wardana et al. (2022) was low, who reported iron, zinc, and calcium levels of 3.47mg, 5.46mg, and 747.40 mg in moringa leaf extract, respectively, despite Onyekwere. (2014) found high calcium (2.09g/100g), zinc (0.005g/100g), and iron (0.03g/100g). The difference between the results is attributable to variances in moringa species and climate change. Still, these findings demonstrate that *m. oleife* has a high concentration of vitamin A, sometimes known as an antioxidant. The proximate

analysis results and mineral content indicate that moringa leaf extract could improve food's nutritional value and acts as a functional ingredient.

4.5.3 Sensory acceptability of mango nectars blended with moringa leaf extract

The sensory analysis revealed that the unblended mango nectar received a higher mean score than blended mango nectar and that adding more moringa leaf extract decreased the overall scores for each sensory attribute. This might be because most participants were unfamiliar with the taste of moringa leaf extract and the slightly green color of mango nectar. The decreased sensory acceptability of mango nectar with increased moringa leaf extract ratio in the formulation might be attributed to the lipoxidase enzyme producing an unpleasant (distinctive) smell from *moringa oliefera* leaves oil and generating unpleasant taste due to its tannin content (Ardhanareswari, 2019). Similar findings indicated that adding *m.oleifera* through several food samples decreased sensory acceptability (Boateng et al., 2019). These findings corroborated with those of Orman et al. (2022), who found that increasing the amount of moringa leaf extract in a functional beverage (pineapple, carrot, and ginger flavor) resulted in a flavor that panelists disliked and that reducing the amount of moringa leaf extract to the bare minimum resulted in a juice with the highest mean score for overall acceptability. Rh et al. (2019b) showed that a beverage containing more than 15% moringa leaf extract blended with beetroot juice generated more moringa flavor. However, beverages containing less than 15% moringa leaf extract didn't offer a taste as satisfying as the prepared beverage. Adding more than 12.5% moringa leaf extract resulted in a drop in overall acceptability in this research work, while a moderate amount of MLE (10% and 12.5%) resulted in high consumer acceptability.

4.5.4 Nutritional composition of mango-moringa blended nectar

Mango nectar blended with moringa leaf extract had a significantly higher nutritional value than unblended mango nectar. This may be because moringa leaf extract has the highest nutritional value. According to the findings, increasing the proportion of moringa leaf extract in the formulation from 10% to 12.5% lowered the moisture. This

was in agreement with Akelom et al. (2022), who found that cactus pear fruit-based jellies enhanced with moringa leaf extract had lower moisture content levels.

Compared to the mango nectar blended with 10 and 12.5%, MLE had higher ash content than unblended mango nectar (control). This finding of increasing ash content levels with the addition of moringa leaf extract proportions was consistent with the findings of Manaois (2013), who found increasing ash content levels with increasing *moringa oleifera* substitution in the formulations. Shiriki et al. (2015) also found a substantial increase in ash content in supplemental food produced from maize, soybean, and peanut with *M. oleifera* leaf powder supplementation.

Adding *m.oleifera* leaf extracts to mango nectar resulted in a high protein content. Similarly, an observation was reported by Sengev et al. (2013), who reported that *moringa oleifera* powders increased the protein content of bread and biscuits, respectively. Yessuf et al. (2020) reported that adding moringa leaf extract to moringa-carrot and moringa-avocado drinks increased their protein content. The low-fat content of *moringa oleifera* leaf extract may explain why there was a slight fluctuation in the crude fat content of mango-moringa nectar (Ogbe and Affiku, 2011).

The finding showed that the fiber content of mango nectar increased with the addition of moringa leaf extract. This might have occurred because *moringa oliefera* leaves had higher fiber. A similar result was observed by Shiriki et al. (2015), who found that adding *moringa oleifera* leaf powder to the diet increased fiber content.

As the proportion of moringa leaf extract increased, the carbohydrate content of the blended mango nectar dropped. This may be related to moringa leaf extract's lower carbohydrate content (Shiriki et al., 2015). In addition, the apparent higher carbohydrate contents obtained from unblended samples (control) compared to blended samples (F3 and F6) may be due to low moisture contents in the unblended samples. The carbohydrate content reported in this study was similar to Aderinola (2018).

The mango nectar's vitamin A content was increased by adding moringa leaf extract. This finding was consistent with Bassey et al. (2020), who reported that the vitamin A content of *moringa oleifera* leaf extract increased the vitamin A content of Zobo drinks juice.

This finding demonstrated that as the quantity of moringa leaf extract in the formulation increased, the calcium, zinc, and iron content of the mango nectar blended increased. Glover-Amengor et al. (2017) found *moringa oleifera* to be an excellent mineral source. This finding is in line with those reported by Aderinola (2018), who evaluated the nutritional value of smoothies enriched with moringa leaves: pineapple (43.5%), banana (38.5%), apple (13.5%), and moringa leaves (4.5%), respectively. This might be because moringa leaf extract is rich in minerals.

4.6 CONCLUSION

This study showed that F3 (25:12.5% Apple mango pulp-moringa leaf extract) and F6 (25:10% Tommy Atkin mango pulp-moringa leaf extract) had the most acceptable color, smell, taste, texture, mouth feel, and overall acceptability Results indicated. This study showed that processing mango fruits could reduce the amount of food lost after harvest and make them healthier by adding moringa oleifera leaf extract with improvement in protein, fat, fiber, carbohydrate, energy, vitamin A, Ca, Zn, and Fe content as well as overall sensorial acceptability; therefore, access to fruit when out of season through fortified mango nectar, and reduction in malnutrition in the community. Furthermore, compared to Tommy Atkin's mango nectar blended with moringa leaf extract, Apple mango nectar blended with moringa leaf extract contained higher levels of vitamins and minerals. Mango flavor should be added appropriately to retain the mango flavor and taste in the mango-moringa nectar. The antioxidants and nutrients in mango nectar got better when moringa leaf extract was added.

CHAPTER FIVE: EFFECT OF STORAGE ON MICROBIOLOGICAL AND PHYSICOCHEMICAL PROPERTIES OF MANGO-MORINGA BLENDED NECTAR

5.1 Abstract

Innovative technology extends juice shelf life and improves nutritional value in mango nectar. Environmental factors and enzymes affect quality during transportation, causing significant loss. Microbiological, sensory, chemical, and phytochemical changes were determined during 90 days of storage at ambient temperature (22-28^{o}C) and refrigeration (4±1^{o}C) after a 30-day interval using a completely randomized design. The effect of storage on the most acceptable mango-moringa nectar was monitored as follows: the accepted formula was made in triplicate (150 bottles): F1 (control Apple mango nectar), F3 (Apple mango nectar enriched with 12.5% moringa leaf extract), F5 (control Tommy Atkin mango nectar), and F6 (Tommy Atkin mango nectar enriched with 10% moringa leaf extract). Three hundred unblended and blended apple and Tommy Atkin mango nectar bottles were stored at room and refrigeration, with four evaluated at room and four at refrigerator collected randomly. Chemical and phytochemical properties were determined using AOAC methods. Microbiological results showed no detection of yeast or mold. The results showed that the sensory acceptability varied significantly ($p<0.05$) during storage, with mango-moringa nectar overall acceptance increased with storage at both storage conditions. The results showed that the vitamin C of both varieties statistically differed ($p<0.05$) during storage. The study found minimal (less than 50%) vitamin C, total phenolics, and flavonoids loss in mango nectar enriched with 12.5% moringa leaf extract at chilled and room temperature. The most significant loss (more than 50%) was observed in mango nectar enriched with 10% moringa leaf extract at refrigeration and room temperature at 90 days, possibly due to oxidation and degradation. Apple mango nectar blended with moringa leaf extract, is satisfactory organoleptically and preserves more nutrients than Tommy Atkin's enriched, and it can be considered for scaling up in commercial production.

5.2 Introduction

Perishable fruits are thermally processed to extend their shelf life. Pasteurization is used to reduce the bacteria population and inactivate natural enzymes in high-acid foods (pH<4.6) (Wibowo et al., 2015b). The food industry must produce more functional beverages and provide shelf-stable product (Paken, 2010). A food's shelf life is the

duration during which it may be kept and sold without substantial loss of quality (Kilkast, 2012) . Before launching a new product, manufacturers must set an expiration date (Khasanov and Matveeva, 2020) .

Tests are done to verify or validate a product's acceptable "life" for a specific time, considering technology, storage conditions, and consumer acceptability. Deterioration in food quality might be seen in nutritional content or organoleptic indices (extraneous taste, color loss, change in taste) (Kilkast, 2012).

The sensory analysis uses human sense organs as evaluation "instruments" to detect product quality changes that may be difficult to detect using standard analytical procedures or instruments. Even if a product has strong nutritional and microbiological qualities, consumers may reject it before other aspects reach undesirable levels (Oliveira et al., 2012a).

Sensory characteristics are controlled by enzymatic, chemical, and microbiological processes, whose rates are affected by temperature and time. The study on the deterioration kinetics of sensory characteristics lets us understand how these aspects impact change rate, producing quantitative cause/effect ratios (Teixeira Neto, 2004). Growing populations require affordable, healthy, and safe food; hence, minimally processed perishables are in demand (Corradini, 2018). Poor distribution or storage conditions, such as excessive temperature or humidity, accelerate the deterioration of a food's quality and safety, which lowers its shelf life (Boekel, 2008).

Although mango nectar is rich in vitamin C, but deficient in phytochemicals such as flavonoids and total phenolic (Lebaka et al., 2021b). When exposed to light, oxygen, and the processing technique, vitamin C loses its effectiveness. Mango nectar has a low phytochemical concentration, and degradation causes significant loss. PA’previous studydy has shown that moringa leaf is a nutrient-rich plant that may be added to mango nectar to reduce losses during storage. Pasteurization is used to make shelf-stable mango juice. Physicochemical interactions limit the shelf life of mango juice. Estimating mango juice quality loss throughout processing and storage is challenging due to the variety of degradation mechanisms and their interactions (Wibowo et al., 2018). Mango products lose taste, color, and nutrients over time. Degradation affects consumer acceptability (Oliveira et al., 2012b).

To maintain quality and stability throughout the expiry date, risk factors must be identified, managed, and controlled: temperature variations, mechanical impacts, chemical changes, light exposure, microbiological damage, and organoleptic characteristics (appearance, aroma, taste). To do so, tests are run to assess the product's "life" over a short time, considering technology storage conditions and customer sales (Kilkast, 2012).

A quantitative change may describe the quality deterioration of a food product with one or more indicators, such as nutritional content or organoleptic indicators (extraneous taste, color loss, change in taste) (Khasanov and Matveeva, 2020) .

Lan et al. (2021) examined fresh mango juice's shelf life using its microbiological safety, nutritional content, and sensory qualities (NFMJ). NFMJ can be safely consumed within 8, 4, and 2 hours when stored at 4, 25, and 37^{o}C, respectively, in aby microbiological safety index. As per nutritional and sensory characteristics, NFMJ (non-industrial fresh juice) kept at 4 or 25^{o}C had great quality after 2 hours and just adequate quality after 4 hours.

Mkandawire et al. (2016) assessed the shelf life of mango juice processed at a small scale. The juice was pasteurized, bottled, and stored at 13 and 30^{o}C in 80 plastic bottles. At six weeks of storage, vitamin C loss was most significant (68%) in juice held at 30^{o}C without preservatives, followed by juice stored at 30^{o}C with preservatives (71.43%). The loss was lowest (26.98%) in juice held at 13^{o}C with a preservative. At week 6, there were significant color changes ($p<0.05$) between juices held at 13^{o}C (4.5 with preservative and 4.66 without) and at 30^{o}C (5.02 with preservatives and 7.00 without preservatives). From week 2, juices held at 30^{o}C were regarded as 'poor' in smell (5.91 and 6.25) and flavor (5.66 and 6.91), but juices stored at 13^{o}C were rated as 'nearly identical' to fresh juice in smell (4.25 and 4.58) and taste (5.66 and 6.91). The lowest numbers of bacteria (2.04 x 104 CFU/ml), yeast, and mold (1.72 x 104 CFU/ml) were found in juices held at 13^{o}C with preservative, whereas juices stored at 30^{o}C without preservative had the highest counts of bacteria (2.10 x 108 CFU/ml) and yeast and mold (1.96x 108 CFU/ml). Juices kept at 30°C, and 13°C were projected to have a two-week and four-week shelf life, based on their aroma and flavor, respectively. The combination of refrigeration and preservatives decreased the rate of vitamin C loss, sensory degeneration, and microbiological development.

In real-time stability testing, a product is kept under specified storage conditions and monitored over time. Real-

time stability testing examines items to see whether they have lost their desirable qualities (Magari, 2003). This study examined the effect of storage conditions at ambient temperature (22 to 28^{o}C) and refrigeration temperature (4±1^{o}C) on the microbiological, sensory analysis, chemical, and phytochemical properties of mango-moringa nectar.

5.3 Materials and Methods

5.3.1 Sample acquisition and Preparation

Tommy Atkin and Apple mangoes (500 pieces each) (Figure 1) were purchased from smallholder farmers in Machakos County and stored at room temperature (25±2^{o}C, 47% RH) for five days to ripen. The ripe fruit was separated to separate decaying fruit from well-formed and firm, insect and disease-free, mechanically-free fruit, rinsed with tap water, weighed, peeled, deseeded, and pulped in a pulping machine equipped with a 0.5mm stainless steel screen (D. K. Engineering, Kenya). The pulps were pasteurized (70^{o}C for 10 minutes) and preserved with 300 ppm sodium metabisulfite (FAO, 2005; Omayio et al., 2022). Pasteurized mango pulp was hot-filled into 5 L PET plastic bottles at 55^{o}C and kept at room temperature (25±2^{o}C, 47% humidity) until further processing.

Fresh *Moringa oleifera* leaves (50 kg) (Figure 1) were removed from their branches, cleaned, sliced, and blanched for 3 minutes at 90^{o}C. The blanched leaves were immersed in 10±2^{o}C water for 3 minutes to avoid further heating, then crushed with 200ml of treated water per 100g of blanched moringa leaf. The extract was obtained using a hydraulic press. The extract was filtered to remove pomace and chilled to -20^{o}C for further usage (Naa et al., 2013; Rh et al., 2019b).

Fig 5.1: Pictures of mango fruit variety and moringa leaves

5.3.2 Mango nectar formulation, processing, and storage

Blended mango-moringa nectar was made with 25% mango pulp (from both Tommy Atkin and Apple mango fruit) and 0, 10, 12.5, and 15% of moringa leaf extract. Water, sugar, citric acid, carboxymethyl cellulose (CMC), and potassium metabisulfite were added to finalize the preparation following Kenyan standards. The most acceptable mango nectar blended with moringa leaf extract was prepared in triplicate using 25% mango pulp blended with 10 and 12.5% moringa leaf extract, water, sugar, citric acid, carboxymethyl cellulose (CMC), and potassium metabisulphite, as shown in Table 5.1. A control containing 25% mango pulp (from Apple and Tommy Atkin) and other ingredients except the moringa leaf extract was prepared. The mango nectar blended with moringa leaf extract was pasteurized at 70°C for 10 minutes before being filled hot at 55°C into 300 mL PET plastic bottles and cooled in tap water for two minutes (Ishara and Gunasena, 2021).

Table 5.1: Different formulations of mango-moringa nectar accepted

Treatment	The portion of ingredients (%)							
Formulations	puree	Moringa leaf extract	Water	Sugar	Citric Acid	Stabilizer	Preservative	Product Name
F1	25	0	64.73	10	0.1	0.15	0.02	Control
F3	25	12.5	52.23	10	0.1	0.15	0.02	M-mn
F5	25	0	64.73	10	0.1	0.15	0.02	Control
F6	25	10	54.73	10	0.1	0.15	0.02	M-mn

The mango-moringa nectar component is a 100% mixture design of developed products for both mango varieties, with M-mn (mango-moringa nectar), with F1: Apple mango nectar control, F3: Apple mango nectar enriched with 12.5% MLE, F5: Tommy Atkin mango nectar control and F6: Tommy Atkin mango nectar enriched with 10% MLE.

5.3.2 Sensory Evaluation of Mango-moringa Nectar

The sensory evaluation of blended and unblended mango nectar was conducted based on appearance, odor, taste, texture, mouth feel, and overall acceptability. Thirty untrained consumers (15 males and 15 females; ages 20 to 54) were recruited at random based on ethics through personal communication and their willingness to participate in this study. They included participants from the Faculty of Agriculture, Department of Food Science, Nutrition, and Technology at the University of Nairobi. Panelists evaluated Apple and Tommy Atkin mango-moringa nectar samples stored at ambient temperature (22 to 28^{o}C) and refrigeration temperature (4 ± 1^{o}C) for 90 days following a 30-day interval, utilizing booths equipped with ambient daylight and equipped with palatable filtered water for rinsing the mouth before and after each formula being tested. Each consumer rated the samples on a seven-point hedonic scale, as outlined by Larmond (1997) , where 1 indicates strongly disliked, and 7 represents extremely liked. Storage studies were conducted on the most popular formulations.

5.3.3 Storage study of acceptable mango blended nectar with moringa leaf extract

From the developed formulations, the best mango-moringa blended nectars, F1 (control for Apple mango), F3 (Apple mango nectar enriched with 12.5% moringa leaf extract), F5 (control for Tommy Atkin mango), and F6 (Tommy Atkin mango nectar enriched with 10% moringa leaf extract), were chosen for a 3-month storage trial. The product was manufactured in triplicate using the best acceptable formulation, with fifteen liters from each formula multiplied by three times four for a total of one hundred eighty liters. Three hundred bottles of unblended and blended apple and Tommy Atkin mango nectar were stored at room temperature (22 to 28^{o}C), while the remaining 300 bottles were held at refrigeration temperature (4±1^{o}C). For unblended and blended Apple and Tommy Atkin mango nectar, sixteen bottles were randomly evaluated with each in duplicate; eight (F1, F2, F5, and F6) at room temperature and eight (F1, F2, F5, and F6) at refrigeration temperature of each mango nectar were chosen randomly as a sample and then analyzed for the microbiological count, sensory characteristics, pH, TTA, TSS, Vit C, total phenolics, and flavonoids every 30 days for 90 days.

5.3.4 Analytical methods

5.3.4.1 Enumeration of Yeast and Molds

The presence of yeast and mold was determined using the acidified dextrose potato agar procedures described by Titarmare et al. (2009) . Five days were spent incubating the plates at 30°C. Colony-forming units per milliliter of the sample (cfu/ml) represent the number of colonies counted and recorded. About 5 ml of tartaric acid was added to 500 ml of the media to prevent bacteria from growing.

5.3.4.1.1 Serial dilution

The serial dilution procedure has been conducted in duplicate, with minor adjustments, as Saeed et al. (2019) described. One (1 mL) sample of juice was added to a 90 mL sterilized sodium chloride solution for mold and yeast observation. It produced a dilution of 1:10. In brief, 1 mL of 1:10 suspension was transferred to a second test tube, constituting 1:100 dilutions. Similarly, dilutions of 1:1,000 were prepared. Dilutions were transferred to sterile Petri plates, followed by media pouring. The Petri plates were then incubated at 30°C for 3-7 days.

5.3.4.1.2 Mold and yeast count

After incubation, the number of colonies was counted and multiplied by the dilution factor to get the number of colony-forming units per milliliter sample (cfu/ml).

The number of colonies=g = Number of colonies × Dilution factor.

Dilution factor = Reciprocal of dilution (e: g:10^{-3} = 10^{3}).

5.3.4.2 Chemical and phytochemical analysis

5.3.4.2.1 pH and titratable acidity

With slight modification, the AOAC (2012) method 960.39 was used to determine the pH. Two buffer standard acid and alkali solutions, designated 4 and 7, were used to calibrate the pH meter. The pH readings were duplicated after inserting the electrode into 50 ml samples. The titratable acidity was determined using the AOAC (2005) method 930.15. In the presence of phenolphthalein, 10 milliliters of samples were titrated with 0.1 N NaOH; the percentage value was expressed and performed in duplicate.

5.3.4.2.2 Total soluble solid

The total soluble solid TSS was determined using a hand-held refractometer (SK106-SATO, Japan) in line with the AOAC (2012) method 960.39. The reading in degree brix was taken directly after a sample drop was placed on the refractometer's display. Readings were done in duplicate.

5.3.4.2.3 Vitamin C content

Using the AOAC (2005) method 967.2 for converting 2,6-standardized dichlorophenolindophenol (DCPIP) solution to a colorless dye, the vitamin C level was assessed twice. Through triplicate titrations with a standardized ascorbic acid solution, the DCPIP solution was standardized. 10 g of the sample was weighed, and 50 ml of a 5% trichloroacetic acid (TCA) solution were added until the flask was filled. The solution was titrated in duplicate against the DCPIP solution using ten (10 mL) of the solution. The amount of vitamin C was measured in mg per 100g of the sample's dry weight.

5.3.4.2.4 Total phenolic content

The total phenolic content was assessed using a modified Folin-Ciocalteu method described by Prior et al. (2005) with minor modifications. Two milliliters of the sample were added to ten milliliters of methanol (80%), which was then agitated and centrifuged overnight. Approximately 2.5 ml of folin was added to 1 ml of the solution. The resulting solution was raised to a final volume of 10 ml by adding 2 ml of sodium carbonate solution (5% w/v) and distilled water. The mixture was incubated at 45^{o}C for 15 minutes. The absorbance was measured at 765 nm and compared to a reference value. Calibration curves were generated using a standard gallic acid solution. The results were expressed as gallic acid equivalents (GAE) mg /100g.

5.3.4.2.5 Total flavonoids content

The flavonoid content was determined using a colorimetric approach, as described by Naksuriya and Okonogi (2015), with a slight adjustment. Two (2 mL) samples were mixed with 10 mL of 80% methanol, agitated, and centrifuged overnight. Four (4ml) of distilled water was added to one (1ml) of the combination (sample juice + methanol), which was then left for 15 minutes. After 15 minutes, 2 mL of NaOH (1 M), 0.3 mL of $AlCl_3$ (1 percent w/v), and 0.3 mL of $NaNO_2$ (5 percent w/v) were added to the mixture (juice sample + methanol+ distilled water). The resultant solution was then diluted to a final amount of 10 mL with distilled water. The absorbance was measured at 510 nm. The calibration curves were constructed using A (+)-standard catechin solution, and the findings were expressed as (QE) mg/100g of catechin equivalents.

5.4 Data analysis

All tests were performed in duplicate, and the results were presented as means±SD. The statistical significance of differences was established using a one-way analysis of variance (one-way ANOVA) with Microsoft Excel and STATA software version 12 to analyze the data, followed by Bonferroni's mean separation test to test for significant differences. P-values less than 0.05 were deemed significant.

5.5 Results

5.5.1 Phytochemical composition of moringa leaf extract

The phytochemical analysis of *Moringa oleifera* leaf extract (M.O.L.E.) showed statistically significant ($p<0.0001$) differences between the total phenolics and flavonoids, as shown in Figure 5.2. The number of phenols and flavonoids in moringa leaf extract was 12787.3±113.27 GAE mg/100g and 8025.1±670.25 QE mg/100g dry weight basis, respectively. These compounds have been reported to possess strong antioxidant and free radicals scavenging activity.

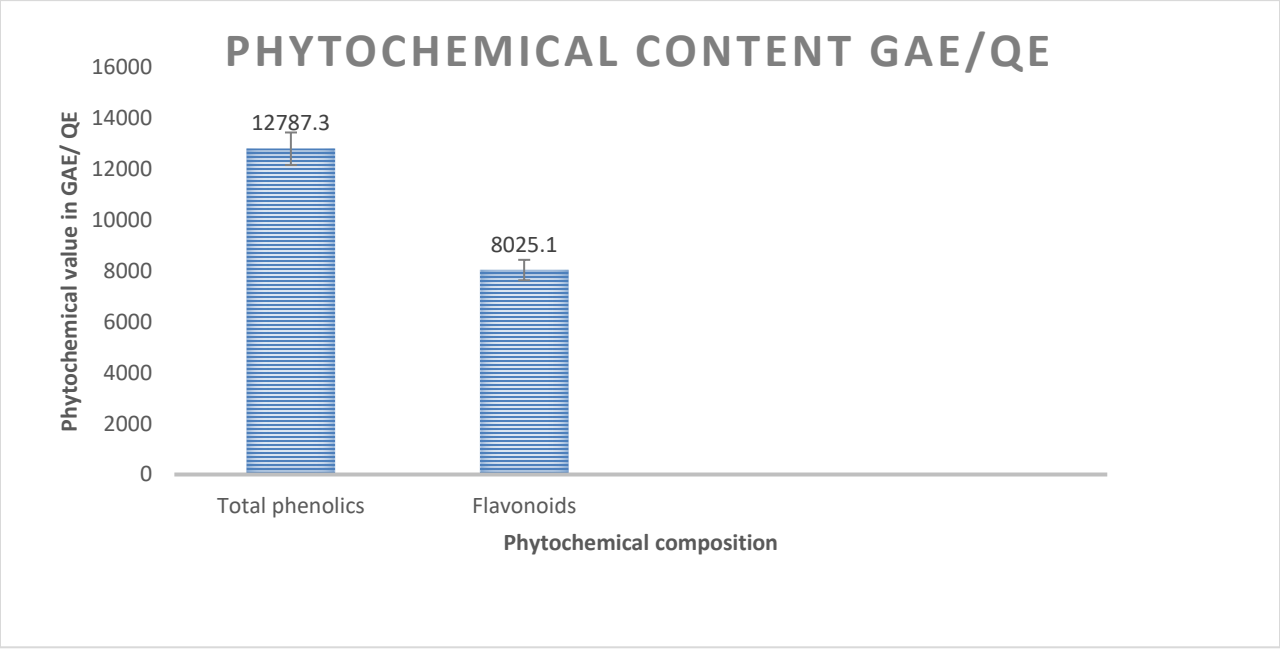

Figure 5.1: Total phenolics and flavonoid content of moringa leaf extract. The bar indicates the standard error of the mean.

5.5.2 Microbiological properties of unblended and blended mango-moringa nectar during storage

The microbiological findings revealed the absence of yeast and mold. This might be attributed to the high concentration of phytochemicals in moringa leaf extract, which has antibacterial and antifungal properties, and proper manufacturing procedures (Gopalakrishnan et al., 2016; Salem et al., 2015).

5.5.3 Sensory Evaluation during storage

As indicated in Tables 5.2 and 3, mango-moringa nectar stored at refrigeration (4±1^{o}C) had a higher mean score than mango-moringa nectar stored at ambient temperature (22 to 28^{o}C) because higher temperatures accelerated deterioration and sensory changes. Increasing storage time and temperature affected the product's appearance, odor, taste, texture, mouth feel and overall acceptability.

Table 5.2: Sensory attributes of Apple mango nectar enriched with 12.5% Moringa leaf extract stored at ambient and chilled conditions for 90 days

Storage condition	Storage days	Product	Sensory Properties					
			appearance	odor	taste	texture	mouthfeel	Overall acceptability
	0	F1	6.73±0.57^{f}	6.09±0.27^{b}	6.12±0.27^{c}	5.82±0.25^{a}	5.82±0.27^{ab}	6.27±0.23^{a}
Ambient		F3	4.48±1.60^{ac}	3.45±0.27^{e}	4.52±0.27^{ab}	5.06±0.25^{a}	4.64±0.27^{ab}	4.73±0.23^{bc}
	30	F1	6.43±0.82^{def}	5.97±0.28^{db}	6.1±0.29^{c}	6.07±0.26^{a}	6.0±0.28^{b}	6.30±0.24^{a}
		F3	4.07±1.53^{c}	3.6±0.28^{cef}	3.93±0.29^{a}	4.87±0.26^{b}	4.53±0.28^{a}	4.27±0.24^{b}
	60	F1	5.32±1.31^{abd}	4.46±0.29^{acef}	4.93±0.30^{abc}	5.11±0.27^{a}	5.18±0.29^{ab}	5.25±0.25^{abc}
		F3	5.11±1.23^{abc}	5.04±0.29^{abcd}	4.61±0.30^{ab}	5.11±0.27^{a}	5.07±0.29^{ab}	5.46±0.25^{abc}
	90	F1	5.19±1.62^{abcd}	4.93±0.29^{abcdf}	4.70±0.30^{abc}	5.11±0.27^{a}	5.30±0.30^{ab}	5.22±0.26^{abc}
		F3	5.48±1.42^{abde}	4.81±0.30^{abcdef}	4.81±0.30^{abc}	5.11±0.27^{a}	4.89±0.30^{ab}	5.15±0.26^{abc}
At 4^{o}C	0	F1	6.72±0.58^{ef}	6.09±0.27^{b}	6.09±0.28^{c}	5.84±0.25^{a}	5.81±0.28^{ab}	6.28±0.23^{a}
		F3	4.56±1.64^{ac}	3.53±0.27^{ef}	4.59±0.27^{ab}	5.06±0.24^{a}	4.68±0.28^{ab}	4.76±0.23^{bc}
	30	F1	5.96±1.43^{bdef}	5.57±0.29^{abd}	5.89±0.30^{bc}	6.0±0.27^{a}	5.75±0.29^{ab}	6.04±0.25^{a}
		F3	4.71±1.56^{abc}	4.29±0.29^{acef}	4.5±0.30^{ab}	4.89±0.27^{b}	4.89±0.29^{ab}	4.71±0.25^{bc}
	60	F1	5.54±1.35^{abdef}	5.43±0.29^{abd}	4.82±0.30^{abc}	5.46±0.27^{a}	5.46±0.29^{ab}	5.61±0.25^{ac}
		F3	5.29±1.41^{abcd}	5.04±0.29^{abcd}	5.18±0.30^{abc}	4.93±0.27^{a}	5.29±0.29^{ab}	5.29±0.25^{abc}
	90	F1	5.57±1.29^{abdef}	4.71±0.29^{abcdef}	4.79±0.30^{abc}	5.36±0.27^{a}	5.32±0.29^{ab}	5.36±0.25^{abc}
		F3	4.75±1.51^{abc}	4.57±0.29^{acdef}	4.43±0.30^{ab}	4.82±0.27^{b}	4.93±0.29^{ab}	5.11±0.25^{abc}
P-value			<0.0001	<0.0001	<0.0001	<0.0009	<0.0008	<0.0001

Values (means ± standard deviation) with different superscript letters along the columns are significantly different at $p<0.05$ (Bonferroni's test). With F1: control and F3: Apple mango nectar enriched with 12.5% moringa leaf extract.

Table 5.3: Sensory attributes of Tommy Atkin mango nectar enriched with 10 % Moringa leaf extract stored at ambient and chilled conditions for 90 days

Storage condition	Storage days	Product	Sensory Properties					
			appearance	odor	taste	texture	mouthfeel	Overall acceptability
	0	F5	6.73±0.26^{c}	6.09±0.28^{b}	6.12±0.28^{c}	5.82±0.27^{a}	5.82±0.28^{a}	6.27±0.25^{b}
Ambient		F6	4.48±0.26^{ab}	3.45±0.28^{c}	4.52±0.28^{ab}	5.06±0.27^{ab}	4.64±0.28^{ab}	4.73± 0.25^{a}
	30	F5	5.83±0.27^{bc}	5.37±0.29^{ab}	4.87±0.30^{abc}	5.20±0.28^{ab}	5.17±0.30^{ab}	5.40±0.26^{ab}
		F6	4.50±0.27^{ab}	4.07±0.29^{ac}	4.00±0.30^{ab}	5.23±0.28^{ab}	4.77±0.30^{ab}	4.33±0.26^{a}
	60	F5	4.96±0.28^{ab}	4.71±0.30^{abc}	4.75±0.31^{abc}	5.11±0.29^{ab}	5.50±0.31^{ab}	5.29±0.27^{ab}
		F6	5.11±0.28^{ab}	5.00±0.30^{ab}	4.93±0.31^{abc}	5.11±0.29^{ab}	5.14±0.31^{ab}	5.36±0.27^{ab}
	90	F5	4.41±0.29^{a}	3.96±0.31^{ac}	3.56±0.31^{b}	4.30±0.29^{b}	4.07±0.31^{b}	4.33±0.28^{a}
		F6	4.85±0.29^{ab}	4.52±0.31^{ac}	4.22±0.31^{ab}	4.89±0.30^{b}	4.85±0.31^{ab}	4.81±0.28^{a}
At 4^{o}C	0	F5	6.72±0.26^{c}	6.09±0.28^{b}	6.09±0.29^{c}	5.84±0.27^{a}	5.81±0.29^{a}	6.28±0.26^{b}
		F6	4.56±0.26^{ab}	3.53±0.28^{c}	4.59±0.28^{ab}	5.06±0.27^{ab}	4.68±0.28^{ab}	4.76±0.25^{a}
	30	F5	5.64±0.28^{abc}	5.25±0.30^{ab}	5.32±0.31^{ac}	5.46±0.29^{ab}	5.36±0.31^{ab}	5.54±0.27^{ab}
		F6	5.29±0.28^{ab}	4.68±0.30^{abc}	4.54±0.31^{ab}	5.25±0.29^{ab}	5.18±0.31^{ab}	5.07±0.27^{ab}
	60	F5	5.39±0.28^{abc}	5.07±0.30^{ab}	5.25±0.31^{ac}	4.85±0.30^{ab}	5.25±0.31^{ab}	5.29±0.27^{ab}
		F6	4.89±0.28^{ab}	4.75±0.30^{abc}	5.00±0.31^{abc}	5.32±0.29^{ab}	5.36±0.31^{ab}	5.29±0.27^{ab}
	90	F5	5.18±0.28^{ab}	4.86±0.30a^{bc}	4.86±0.31^{abc}	5.00±0.29^{ab}	5.29±0.31^{ab}	5.36±0.27^{ab}
		F6	5.04±0.28^{ab}	4.71±0.30^{abc}	4.79±0.31^{abc}	4.52±0.30^{ab}	4.89±0.31^{ab}	4.86±0.27^{a}
P-value			<0.0001	<0.0001	<0.0001	0.0179	0.0041	<0.0001

Values (means ± standard deviation) with different superscript letters along the columns are significantly different at p<0.05 Bonferroni's test). With F5: control and F6: Tommy Atkin mango nectar enriched with 10% moringa leaf extract.

5.5.3.1 Appearance (color)

Storage days affected the color of an unblended Apple and Tommy Atkin mango nectar ($p<0.05$). Under ambient and chilling conditions, unblended Apple mango nectar's color means score decreased from 6.73 to 5.19 and 6.72 to 5.18, whereas Tommy Atkin's decreased from 6.73 to 4.41 and 6.72 to 5.57. The mean score increased from 4.48 to 5.48 and from 4.56 to 4.75 for mango nectar blended with 10 and 12.5% moringa leaf extract, respectively (Tables 5.2 and 3). At 0 and 30 days of storage, the control sample's color mean score was much greater than that of the blended Apple and Tommy Atkin mango nectar. This may be due to amino acids and ascorbic acid losses, which cause color change and off-taste in mango juice (Falade et al., 2004).

5.5.3.2 Odor

Storage days significantly affected the odor of unblended and blended Apple and Tommy Atkin mango nectar ($p<0.05$). The control had a higher odor rating at days 0 through 60 days than Apple mango nectar enriched with 12.5% moringa leaf extract, which decreased at day 90. Unblended Tommy Atkin nectar scored higher from 0 to 30 days, then decreased from 60 to 90 days. The odor rating of unblended nectar decreased from 6.09 to 4.93 and 6.09 to 4.71 in Apple mango nectar, while Tommy Atkin mango nectar decreased from 6.09 to 3.96 and 6.09 to 4.86. Apple mango nectar blended with moringa leaf extract increased from 3.45 to 4.48 and 3.53 to 4.57, whereas Tommy Atkin mango nectar increased from 3.45 to 4.52 and 3.53 to 4.71. (Table 5.2 and 3). Vitamin C losses in mango-moringa nectar must be attributed to fragrance loss and off-flavors (Jimenez, 1999).

5.5.3.3 Taste

Similarly, storage days had a significant ($p<0.05$) effect on the taste of unblended and blended mango nectar, as shown in Table 5.2 and 3. The taste rating of unblended Apple mango nectar decreased from 6.12 to 4.81 and 6.09 to 4.79, while Tommy Atkin mango nectar decreased from 6.12 to 3.56 and 6.09 to 4.86 under room and chilling condition. Mango nectar blended with 12.5% moringa leaf extract decreased from 4.52 to 3.93 at 0 to 30

days, then increased from 4.61 to 4.81 at 60 to 90 days at ambient conditions. At chilling conditions, mango nectar decreased from 4.59 to 4.5 at 0 to 30 days, increased at 60 days (5.18), and decreased at 90 days (4.43). Under ambient conditions, the taste rating of Tommy Atkin mango nectar blended with 10% moringa leaf extract decreased from 4.52 to 4 at 0 to 30 days, increased at 60 days (4.93), and then decreased at 90 days (4.22). Under chilling conditions, the taste rating decreased from 4.59 to 4.54, increased from 60 days (5.25), and then decreased from 90 days (4.79)

5.5.3.4 Texture

The texture of unblended and blended mango nectar was significantly ($p<0.05$) affected by storage days. The control sample exhibited better texture ratings from day 0 to day 30 than those blended with 10 and 12.5% moringa leaf extract. The texture means score for unblended Apple mango nectar increased from 0 to 30 days (5.84 to 6), then remained stable from 60 to 90 days (5.11), but decreased when chilled from 5.82 to 4.3 at 60 and 90 days of storage. After 0, 60, and 90 days at room temperature and chilled temperature, the texture of Tommy Atkin mango nectar (the control) decreased from 5.82 to 4.3 and from 5.84 to 4.85, respectively. It increased after 90 days (5) under chilling temperature. Tommy Atkin's blend with 10% moringa leaf extract increased from 0 to 60 days (5.06 to 5.23) but decreased after 90 days (4.89) under ambient temperature. Under chilling conditions, the texture score increased from 0 to 60 days (5.06 to 5.32) but decreased after 90 days (4.52).

5.5.3.5 Mouthfeel

Storage days had a significant ($p<0.05$) effect on the mouthfeel of unblended and blended mango nectar, as indicated in Tables 5.2 and 3. There was a significant difference between the samples from day 0 to day 30, with the control having a higher mouthfeel score than the blended mango nectar. Unblended Apple mango nectar's mouthfeel score increased from 0 to 30 days (5.82 to 6) and decreased from 30 to 90 days (from 6 to 5.30) under ambient conditions but decreased from 0 to 90 days (5.81 to 5.32) under chilling conditions. The mouthfeel score of Apple mango nectar blended with 12.5% moringa leaf extract decreased from 0 to 30 days (4.64 to 4.53),

increased from 30 to 60 days (4.53 to 5.07), and subsequently decreased at 90 days of storage (4.89). The mouthfeel rating increased under chilling conditions from 0 to 60 days (from 4.68 to 5.29) and then decreased at 90 days (4.93). The control sample of Tommy Atkin mango nectar had a higher mouthfeel score on day 0 (5.82) than on day 90 (4.07), while under the chilling condition, the mouthfeel score decreased from 0 to 60 days (5.81 to 5.25) but increased at 90 days (5.29). Tommy Atkin's blended mango nectar with 10% moringa leaf extract increased from 0 to 60 days (4.64 to 5.14 and 4.68 to 5.36) and decreased after 90 days (4.85 and 4.89) under both storage conditions.

5.5.3.6 Overall acceptability

Storage days had a significant ($p<0.05$) effect on unblended and blended mango nectar's overall acceptability, as presented in Tables 5.2 and 3. An increase was detected at 0 and 30 days (6.27 to 6.30) for unblended apple-mango nectar at ambient temperature, followed by a decrease from 60 to 90 days (5.25 to 5.15) and then a decrease from 0 to 90 days at chilling temperature (6.28 to 5.36). Under both storage conditions, the overall acceptability mean score of blended Apple-mango nectar decreased at 0 and 30 days (from 4.73 to 4.27 and 4.76 to 4.71), increased at 60 days (5.46 and 5.29) and then decreased at 90 days (5.15 and 5.11). The overall acceptability of unblended Tommy Atkin mango nectar dropped from 0 to 90 days at ambient conditions (6.27 to 4.33), while at chilling temperatures, it decreased from 6.28 to 5.29 at 0 to 60 days, followed by an increase at 90 days (5.36). Under ambient conditions, the overall acceptability of blended Tommy Atkin mango nectar increased from 0 to 60 days (4.73 to 5.36) before decreasing at 90 days (4.81). Under chilling conditions, overall acceptability increased from 0 to 60 days (4.76 to 5.29), then decreased at 90 days (4.86).

5.5.4 Changes in chemicals properties of mango-moringa nectar during storage

The effect of storage condition, storage days, and enrichment of moringa leaf extract on the pH of unblended and blended mango nectar was not statistically significant ($p > 0.05$), as shown in Table 5.4 and 5. The pH of unblended and blended mango nectar increased from 0 to 90 days of storage under both storage conditions, from

4.45 to 4.65 at ambient conditions (control), blended from 4.45 to 4.66. At the chilling condition, the control increased from 4.45 to 4.72 and blended from 4.45 to 4.71 (Atkin mango nectar). For Apple mango nectar, at the ambient condition, the control pH varied from 4.51 to 4.73 and blended from 4.64 to 4.75; at the chilling condition, the control pH varied from 4.51 to 4.72 and blended from 4.64 to 4.81.

The TTA of the enriched Tommy Atkin mango nectar was significantly affected by storage conditions, storage period, and moringa leaf extract enrichment, whereby TTA significantly decreased with an increase in storage period. Furthermore, there was a significantly higher decline in TTA in samples stored at ambient conditions compared to samples stored at 4±1°C. Storage condition, storage period, and moringa leaf extract enrichment had no significant influence on the TTA of enriched Apple mango nectar ($p= 0.4055$). The TTA of both unblended and blended mango nectars decreased with storage time, as seen in Tables 5.4 and 5.

The TSS of unblended and blended mango nectar during storage as shown in Tables 5.4 and 5. Storage condition, storage period, and moringa leaf extract enrichment had no significant influence on the TSS of enriched Tommy Atkin and Apple mango nectar ($p= 0.265, 0.4055$). Tommy Atkin, mango nectar TSS, remained unchanged (13.5^{o}Brix) from 0 to 60 days and increased after 90 days (13.8^{o}Brix). The TSS of unblended apple mango nectar remained unchanged at both storage temperatures. However, with the addition of 12.5% moringa leaf extract, the TSS increased from 13.9 to 14 at 60 and 90 days of storage.

The enrichment of mango nectar with moringa leaf extract and the period of storage had a significant ($p<0.05$) effect on the vitamin C content. The vitamin C content of both unblended and blended mango nectars decreased with time, as shown in Tables 5.4 and 5. According to the results of mango nectar fortified with 12.5% moringa leaf extract, vitamin C loss was minor: 36.5% at chilled temperature and 44.65% at room temperature. Maximum vitamin C loss was seen in mango nectar blended with 10% moringa leaf extract, 59.9 % at refrigeration, and 72.6% at room temperature after 90 days of storage, possibly due to oxidation.

Table 5.4: Chemical changes of Apple mango nectar enriched with 12.5% Moringa leaf extract stored for 90 days at ambient temperature and 4°C

Storage conditions	Days	Product	pH	TTA (g/lactic acid)	TSS	Vitamin C (mg/100g)
Ambient	0	F1	4.51 ± 0.02^{a}	0.18 ± 0.002^{b}	13.50 ± 0.02^{a}	63.41 ± 1.01^{d}
		F3	4.64 ± 0.02^{a}	0.20 ± 0.002^{c}	13.50 ± 0.02^{a}	76.69 ± 1.01^{e}
	30	F1	4.56 ± 0.02^{a}	0.17 ± 0.002^{ab}	13.50 ± 0.02^{a}	50.82 ± 1.01^{c}
		F3	4.65 ± 0.02^{a}	0.19 ± 0.002^{bc}	13.50 ± 0.02^{a}	67.69 ± 1.01^{d}
	60	F1	4.60 ± 0.02^{ab}	0.16 ± 0.002^{ab}	13.50 ± 0.02^{a}	39.91 ± 1.01^{b}
		F3	4.70 ± 0.02^{ab}	0.18 ± 0.002^{b}	13.50 ± 0.02^{a}	52.47 ± 1.01^{c}
	90	F1	4.73 ± 0.02^{bc}	0.15 ± 0.002^{a}	13.50 ± 0.02^{a}	33.75 ± 1.01^{a}
		F3	4.75 ± 0.02^{c}	0.18 ± 0.002^{b}	13.93 ± 0.02^{b}	42.46 ± 1.01^{ab}
At 4°C	0	F1	4.51 ± 0.02^{a}	0.18 ± 0.002^{b}	13.50 ± 0.02^{a}	63.41 ± 1.38^{de}
		F3	4.64 ± 0.02^{a}	0.20 ± 0.002^{c}	13.50 ± 0.02^{a}	76.69 ± 1.38^{f}
	30	F1	4.55 ± 0.02^{a}	0.17 ± 0.002^{ab}	13.50 ± 0.02^{a}	53.81 ± 1.38^{c}
		F3	4.75 ± 0.02^{c}	0.19 ± 0.002^{bc}	13.50 ± 0.02^{a}	70.03 ± 1.38^{ef}
	60	F1	4.70 ± 0.02^{ab}	0.17 ± 0.002^{ab}	13.50 ± 0.02^{a}	45.97 ± 1.38^{b}
		F3	4.75 ± 0.02^{c}	0.18 ± 0.002^{b}	13.50 ± 0.02^{a}	57.09 ± 1.38^{cd}
	90	F1	4.71 ± 0.02^{b}	0.16 ± 0.002^{a}	13.50 ± 0.02^{a}	36.79 ± 1.38^{a}
		F3	4.81 ± 0.02^{d}	0.17 ± 0.002^{ab}	14.00 ± 0.02^{b}	48.68 ± 1.38^{ab}
P value			>0.1239	>0.4055	>0.4055	<0.0385

Values (means ± standard deviation) with different superscript letters along the columns are significantly different at $p<0.05$ Bonferroni's test).

With F1: Control, F3: apple mango nectar blended with 12.5% moringa leaf extract

Table 5.5: Chemical changes of Tommy Atkin mango nectar enriched with 10% Moringa leaf extract stored for 90 days at ambient temperature and at 4°C

Storage conditions	Days	Product	pH	TTA (%)	TSS (^{Brix})	Vitamin C (mg/100g)
Ambient	0	F5	4.45±0.05^{a}	0.18±0.001^{a}	13.50±0.04^{a}	18.08 ± 0.55^{c}
		F6	4.45±0.01^{a}	0.20±0.001^{a}	13.50±0.04^{a}	24.18 ± 0.55^{e}
	30	F5	4.49±0.04^{a}	0.16±0.001^{ab}	13.50±0.04^{a}	11.98 ± 0.55^{b}
		F6	4.47±0.02^{a}	0.19±0.001^{ab}	13.50±0.04^{a}	18.91 ± 0.55^{c}
	60	F5	4.55±0.02^{b}	0.12±0.001^{d}	13.50±0.04^{a}	8.44 ± 0.55^{a}
		F6	4.55±0.01^{b}	0.16±0.001^{e}	13.50±0.04^{a}	13.17 ± 0.55^{b}
	90	F5	4.65±0.03^{c}	0.09±0.001^{f}	13.50±0.04^{a}	3.51 ± 0.55^{d}
		F6	4.66± 0.01^{c}	0.10±0.001^{f}	13.50±0.04^{a}	6.62 ± 0.55^{a}
At 4°C	0	F5	4.45±0.05^{a}	0.18±0.001^{a}	13.50±0.04^{a}	18.08 ± 0.51^{c}
		F6	4.45±0.01^{a}	0.20±0.001^{a}	13.50±0.04^{a}	24.18 ± 0.51^{f}
	30	F5	4.55±0.02^{b}	0.17±0.001^{ab}	13.50±0.04^{a}	14.52 ± 0.51^{b}
		F6	4.51±0.02^{b}	0.18±0.001^{ab}	13.50±0.04^{a}	21.09 ± 0.51^{e}
	60	F5	4.66±0.02^{cd}	0.16±0.001^{bc}	13.50±0.04^{a}	8.77 ± 0.51^{a}
		F6	4.68±0.02^{cd}	0.18±0.001^{bc}	13.50±0.04^{a}	16.13 ± 0.51^{bc}
	90	F5	4.72±0.01^{d}	0.15±0.001^{c}	13.50±0.04^{a}	5.97 ± 0.51^{d}
		F6	4.71±0.02^{d}	0.17±0.001^{c}	13.50±0.04^{a}	9.68 ± 0.51^{a}
P value			>0.8212	<0.0308	>0.265	<0.0159

Values (means ± standard deviation) with different superscript letters along the columns are significantly different at $p<0.05$ Bonferroni's test).

With F5: control and F6: Tommy Atkin mango nectar blende with 10% moringa leaf extract.

5.5.5 Changes in phytochemicals properties of mango-moringa nectar during storage

Moringa leaf extract enrichment and storage period significantly ($p<0.05$) affected total phenolics and flavonoids of unblended and blended mango nectar. Mango nectar blended with 10 and 12.5% moringa leaf extract had higher total phenolics and flavonoids than unblended mango nectar. The total phenolics and flavonoid content of Tommy Atkin and Apple mango nectar decreased over time at ambient and chilling temperatures, with a tremendous loss at 90 days, as shown in Tables 5.6 and 5.7. The highest total phenolic and flavonoid loss was recorded in unblended and blended Tommy Atkin mango nectar stored at ambient temperature. In mango nectar supplemented with 12.5% moringa leaf extract, the loss of total phenolics and flavonoids was minimal: 15.7% and 11.3%, respectively, at chilled temperature and 38.4% and 22.6%, respectively, at room temperature. The mango nectar enriched with 10% moringa leaf extract had the highest loss of total phenolics and flavonoids, which was 58.1% and 49.8%, respectively, at refrigeration temperature and 63.5% and 59.5% at room temperature after 90 days of storage. This was due to degradation.

Table 4: Changes in phytochemical characteristics of Apple mango nectar enriched with 12.5% Moringa extract stored for 90 days at ambient temperature and 4°C

Storage conditions	Days	Product	Phenolics (mg GAE/100g)	Flavonoids (mg QE/100g)
	0	F1	1.539 ± 1.82^{e}	2.384 ± 1.84^{d}
		F3	169.36 ± 1.82^{f}	335.61 ± 1.84^{g}
	30	F1	1.139 ± 1.82^{c}	2.087 ± 1.84^{c}
		F3	133.02 ± 1.82^{d}	299.22 ± 1.84^{f}
	60	F1	0.906 ± 1.82^{a}	1.954 ± 1.84^{b}
		F3	117.55 ± 1.82^{c}	276.85 ± 1.84^{e}
	90	F1	0.859 ± 1.82^{a}	1.783 ± 1.84^{a}
		F3	104.28 ± 1.82^{b}	259.58 ± 1.84^{d}
At 4°C	0	F1	1.539 ± 2.60^{bc}	2.384 ± 1.62^{c}
		F3	169.36 ± 2.60^{d}	335.61 ± 1.62^{f}
	30	F1	1.351 ± 2.60^{a}	2.207 ± 1.62^{b}
		F3	160.47 ± 2.60^{cd}	316.83 ± 1.62^{e}
	60	F1	1.069 ± 2.60^{f}	2.159 ± 1.62^{b}
		F3	152.03 ± 2.60^{ab}	310.04 ± 1.62^{e}
	90	F1	0.921 ± 2.60^{e}	2.064 ± 1.62^{a}
		F3	142.72 ± 2.60^{ab}	297.67 ± 1.62^{d}
P value			<0.0001	<0.0001

Values (means ± standard deviation) with different superscript letters along the columns are significantly different at $p<0.05$ Bonferroni's test).

With F1: control, F3: apple mango nectar blended with 12.5% moringa leaf extract

Table 5: Changes in phytochemical characteristics of Tommy Atkin mango nectar enriched with 10% Moringa extract stored for 90 days at ambient temperature and 4°C

Storage conditions	Days	Product	Phenolics (mg GAE/100g)	Flavonoids (mg GAE/100g)
Ambient	0	F5	1.027 ± 2.01^{e}	2.379 ± 1.65^{d}
		F6	160.83 ± 2.01^{g}	308.79 ± 1.65^{g}
	30	F5	0.628 ± 2.01^{c}	1.907 ± 1.65^{c}
		F6	115.69 ± 2.01^{f}	278.25 ± 1.65^{f}
	60	F5	0.467 ± 2.01^{b}	1.241 ± 1.65^{b}
		F6	88.33 ± 2.01^{d}	256.09 ± 1.65^{e}
	90	F5	0.222 ± 2.01^{a}	0.735 ± 1.65^{a}
		F6	58.59 ± 2.01^{c}	124.76 ± 1.65^{b}
At 4°C	0	F5	1.027 ± 1.91^{e}	2.379 ± 1.59^{d}
		F6	160.83 ± 1.91^{g}	308.79 ± 1.59^{f}
	30	F5	0.842 ± 1.91^{d}	1.981 ± 1.59^{c}
		F6	134.57 ± 1.91^{f}	279.66 ± 1.59^{e}
	60	F5	0.563 ± 1.91^{b}	1.619 ± 1.59^{b}
		F6	98.85 ± 1.91^{e}	216.05 ± 1.59^{c}
	90	F5	0.341 ± 1.91^{a}	0.854 ± 1.59^{a}
		F6	67.18 ± 1.91^{c}	154.84 ± 1.59^{b}
P value			<0.0001	<0.0001

Values (means ± standard deviation) with different superscript letters along the columns are significantly different at $p<0.05$ Bonferroni's test). With F5: control and F6: Tommy Atkin mango nectar blende with 10% moringa leaf extract.

5.6 Discussion

5.6.1 Phytochemical composition of moringa leaf extract

The total phenolics and flavonoids content of moringa leaf extract reported in this study corroborated the results of Moyo et al. (2012), who found 40.27g GAE/g and 45.1g QE/g, respectively, of total phenolics and flavonoids. However, the present result showed higher total phenolics and flavonoids content than that of Siddhuraju and Becker (2003), Ma et al. (2017), and Okumu et al. (2016), who reported a total phenolic content of 35.42 mg GAE/g and a total flavonoids content of 79.13 mg QE/g in the aqueous of moringa leaf extract. The observed result may be related to the variable levels of the polarity of the solvents used in the extraction of polyphenolic compounds and hence may significantly contribute to the antioxidant and free radical scavenging abilities. Similar results were revealed by Siddhuraju and Becker (2003), who reported the presence of high phenolic and flavonoid content in *moringa oleifera* leaf extract using methanol as a solvent. This variance may also be attributable to variables such as plant source and variety, maturation stage, post-harvest treatment, processing, and storage (Sreelatha and Padma, 2009) .

5.6.2 Microbiological properties of unblended and blended mango-moringa nectar during storage

The microbiological results of unblended and blended mango nectar reported in this study corroborated the results of Hashemi et al. (2018), who found no yeast or mold count detection in guava whey juice fortified with 1.5 and 2% *moringa oliefera* leaf aqueous extract, respectively. The use of moringa leaf extract in fortified juices has led to a significant increase in the preservative activity (shelf life) of these juices. This is because they contain hydrocarbon, alcoholic, and phenolic compounds that might be considered for microbial inhibition and increased preservative activities (Ali et al., 2015b; Sohaimy et al., 2015 Similar results were reported by Nouman et al. (2014), demonstrated that *moringa oleifera* leaf aqueous extract had antifungal efficacy against both gram-positive and gram-negative fungi.

5.6.3 Sensory Evaluation of mango-moringa nectar during storage

Appearance (color), odor, taste, texture, mouthfeel, and overall acceptability mean score of mango-moringa nectar were affected by the addition of moringa leaf extract (MLE) and storage period. This might be because *moringa oleifera* leaves are naturally greenish due to their high chlorophyll content, which may have interfered with the natural color consumers associate with mango nectar (Govender and Siwela, 2020). The appearance (color) of mango nectars was affected by storage duration and the addition of moringa leaf extract, with the control nectars having a high mean score on days 0 and 30. However, there were no differences in color preference at days 60 and 90, which might be attributed to the degradation of chlorophyll in moringa leaf extract with storage time, turning the mango nectar to the natural color of mango that the sensory panelists preferred. This study corroborated the research conducted by Peñaflorida and Masbaňo (2015) on the acceptability of mango puree enriched with moringa extract (0, 5, 10, and 15 ml), who reported that puree mango enriched with 5 and 10 ml moringa leaves extract was rated as like, while puree mango enriched with 15 ml moringa leaves extract was rated as dislike.

These findings were also similar to those of Mounika et al. (2021) , who reported that moringa leaf extract (10 and 15%) added to ready-to-eat millet snacks led the snacks to develop a dark green color and was not well appreciated. The color means a score of moringa-ready-to-eat millet snacks fortified with 10 and 15% moringa leaf powder was 5.571 and 5.286, respectively.

Similar tendencies were detected in the evaluations of the other characteristics assessed to determine the beverage's quality acceptability. The leaf's seemingly bitter taste considerably impacts the flavor, as shown by the proportion of moringa leaf extract used. These results were near to those reported by Hashemi (2018) , who noted that Treatment 1: fresh *moringa oleifera* leaf extract (FMOLE) 40% + Pineapple 38% + Carrot 20% + Ginger 2% scored 4.03, 3.44, 3.09, 4., and 3.38, respectively, for color, odor, taste, texture, and overall acceptability, and Treatment 3: fresh *moringa oleifera* leaf extract (FMOLE) 60% + Pineapple 28% + Carrot 10% + Ginger 2% scored 3.91, 3.28, 2.66, 4.03, and 3.31, respectively: compared to treatment 2, had slightly lower sensory parameter scores for the following ingredients: fresh *moringa oleifera* leaf extract (FMOLE) 50% + Pineapple

38% + Carrot 10% + Ginger 2% (4.03, 3.59, 2.75, 4.16, and 3.47, respectively, for color, odor, taste, texture, and overall acceptability after one month of storage). Moringa leaf extract may influence the natural odor of mango nectar, reducing its sensory acceptability. Moringa leaf extract has a distinct, slightly bitter, disagreeable flavor (Adepoju and Selezneva, 2020; Method, 2015). This might have impacted the odor and flavor of mango-moringa nectar.

This study's low overall acceptability of mango-moringa nectar was comparable to earlier research on moringa-enriched orange juice reported by Hashemi et al. (2018), who found that the overall acceptability scores of controls A (Orange juice 70% + Water 20% + Ginger extract 10%) decreased significantly from 4.65 to 3.88 over one month of storage. The overall acceptability scores of treatments C (Orange juice 70% + M.O.L.E. 20% + Ginger extract 10%) and D (Orange juice 70% + M.O.L.E. 10% + Beetroot juice 10% + Ginger extract 10%) increased significantly after one month of storage in glass bottles, from 3.81 to 3.88 and 3.86 to 4.09, respectively.

5.6.4 Changes in chemicals properties of mango-moringa nectar during storage

The increase in pH might result from the acid hydrolysis of polysaccharides, such as starch, into sucrose, fructose, and glucose. These interactions enhance the sweetness and reduce sourness, increasing pH (Rehman et al., 2014). Rehman et al. (2014) reported that the pH value increased during the storage period in fruit juice concentrates, ranging from 3.81 to 4.98 after 30 days of storage. These findings were consistent with those of the current experiment.

Tommy Atkin and Apple mango nectar have been shown to increase pH while the TTA decreases. The current findings were similar to those of Alaka et al. (2003), who reported that total titratable acidity decreased from 0.71 to 0.46 after four weeks of storage for both fortified and unfortified guava juice stored in different packaging materials due to the breakdown of ascorbic acid and citric acid. These results were supported by Adeogun et al., (2017); Cortés et al., (2008), who reported that leaf extracts could decrease fruit acidity based on their acid-binding qualities by increasing juice pH.

The increase of TTS of unblended and blended mango nectar after 90 days of storage might be due to sucrose hydrolysis to invert sugars (Murtaza et al., 2004. The TSS of the current study was low compared to Asati and Kumar (2022), who reported 16.2^{o}Brix of TSS after 90 days in moringa energy drinks blended with pineapple. The current findings were consistent with Rehman et al. (2014), who found that total soluble solids rose from 16.3 to 16.80 over 30 days of storage of pasteurized mango juice concentrates due to the production of water-soluble pectin fractions.

Both control and treated samples stored at ambient and chilling temperatures lost vitamin C during storage. Mango nectar blended with moringa leaf extract had higher vitamin C content than controls. In this case, vitamin C degradation might be caused by ascorbic acid oxidase, cytochrome oxidase, and peroxidase. The vitamin C content most likely decreased since ascorbic acid is light-, oxygen-, and temperature-sensitive (Khan et al., 2021). These findings were consistent with Hashemi et al. (2018a), who found that orange juice supplemented with 10% moringa leaf extract lost vitamin C after 1 month at 4±1°C. Ajayi et al. (2016) reported a 0.5 percent and 1% drop in vitamin C content after eight weeks of storage of zobo juice preserved with moringa leaf and ginger extracts, respectively.

Similarly, Hashemi et al. (2018b) reported a decrease in vitamin C content during the storage of mixed fruit and vegetable juice preserved with *M. oleifera* leaf extract at 40%, 50%, and 60% concentrations. Hussain et al. (2010) found a reduction in vitamin C in the juice that had been refrigerated for 90 days. Mkandawire et al. (2016) found that vitamin C losses in mango juices stored for six weeks were 79.4% at 30 °C without preservatives and 71.43 with preservatives, 26.98% with preservatives, and 64.30 % without preservatives at 13^{o}C. Vitamin C is a sensitive, water-soluble vitamin that deteriorates significantly after ordinary processing (e.g., heat treatment and drying), resulting in a rapid loss. Even if high control or optimal processing conditions are applied, post-processing handling is still a factor (Giannakourou and Taoukis, 2021) .

5.6.5 Changes in the phytochemical composition of mango nectars blended with moringa leaf extract

Tommy Atkin and Apple mango nectar supplemented with 10 and 12.5% moringa leaf extract had more phenolics and flavonoids than controls due to the addition of moringa leaf extract. In this investigation, the total phenolic and flavonoid content of both the control and enhanced mango nectar decreased with storage time at ambient and chilling temperatures. This degradation could be associated with the prevention of microbial growth, such as yeast and molds, and the effect of storage conditions (Castro-López et al., 2016). Ali et al. (2015) found similar effects in guava whey beverages containing *moringa oleifera* leaf extract. This conclusion was consistent with Hashemi et al. (2018), who found that phenolic components in orange juice enriched with moringa leaf extract were reduced by 17.7% after storage for up to 1 month compared to the control (9.3%). Flavonoid content decreased with storage time in both control and enhanced samples. These results corroborated the research by Rizk et al. (2009), who found that the total flavanone content of mango juices decreased by 1.4% after six months of storage at ambient and refrigerated temperatures, respectively.

This finding was consistent with that of Potisate et al. (2015), who reported a decrease in flavonoid content during storage of dried leaves in polypropylene (PP) or high barrier (PET/Al/PE) packaging for up to six months.

5.7 Conclusion

The sensory characteristics (color, odor, taste, texture, mouthfeel, and overall acceptability) of unblended and blended mango nectar deteriorated as storage time increased. Apple mango nectar (25% mango pulp blended with 12.5% moringa leaf extract and stored at 4±1^{o}C and 22-28^{o}C) was satisfactory organoleptically and maintained more nutrients during storage than Tommy Atkin mango nectar enriched with 10% moringa leaf extract. Apple mango nectar blended with moringa leaf extract preserved more nutrients when stored at a low temperature (4±1^{o}C) and is recommended for commercial production

CHAPTER SIX: GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1. GENERAL CONCLUSION

Apple mango pulp had more Vitamin A, C, calcium, zinc, total phenolics, and flavonoid than Tommy Atkin mango pulp, making it more appropriate for processing into juice and nectar. From the findings, it was clear that moringa leaf extract was rich in calcium, iron, zinc, total phenolics, and flavonoids; making it a good food supplement.

The developed F3 (25:12.5% Apple mango pulp-moringa leaf extract) and F6 (25:10% Tommy Atkin mango pulp-moringa leaf extract) were the most acceptable based on the sensory attribute. This study showed that mango fruits pulp blended with *moringa oleifera* leaf extract led to a high protein, fat, fiber, carbohydrate, energy, vitamin A, Ca, Zn, and Fe content as well as overall sensorial acceptability in mango nectar.

The result during storage of mango nectar revealed no detection of yeast or molds during 90 days of storage due to proper manufacturing and the antifungal properties of moringa leaf extract. Under ambient and chilling temperatures, Tommy Atkin's mango nectar blended with 10% moringa leaf extract lost more than 50% of its vitamin C, total phenolics, and flavonoids after 90 days of storage. In contrast, apple mango nectar enriched with 12.5% moringa leaf extract lost less than 50% of its vitamin C, total phenolics, and flavonoids, making the latter suitable for commercial usage.

6.2 RECOMMENDATION

It is also recommended to the researcher that:

i. More studies should be done to improve the flavor of mango-moringa nectar by integrating rich fruit and vegetables and processing the fruit into items other than nectar.
ii. Additional study be carried out on the influence of packaging on storability to determine the optimal form of packaging.
iii. Assess the efficacity of mango nectar blended with moringa leaf extract on malnourished children and vulnerable populations, including pregnant and lactating mothers.

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APPENDICES

SENSORY EVALUATION QUESTIONNAIRE

Introduction

You are presented with the following **mango-moringa ready-to-**drink nectars; kindly give scores for each attribute listed below on a scale of 1-7, as indicated at the bottom. Kindly rinse your mouth before and after tasting a sample before proceeding with the evaluation.

Date..... Gender..... Respondent Age……..….

Parameters	**Samples**			
	NT	**WN**	**MX**	**DF**
Colour				
Odor				
Taste				
Texture				
Mouthfeel				
Overall Acceptability				

1 = Dislike Strongly

2 = Dislike Moderately

3 = Slightly Dislike

4 = Neither like nor dislike

5 = Like Slightly

6 = Like Moderately

7 = Like Strongly

Please leave a comment ----------

THANK YOU FOR PARTICIPATING

Table 6: proximate composition of moringa leaf extract

product	Moisture (%)	Ash (%)	Fat (%)	Fiber (%)	Protein (%)	Carbohydrates (%)	Energy (kcal/100g)
Moringa Leaf extract	97.22±0.09^{c}	9.68±0.13^{c}	0.79±0.01^{c}	10.54±0.47^{b}	21.09±1.01^{b}	56.95±0.56^{b}	321.51±1.06^{a}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Values are means ± SD. Means with different superscript letters along the columns are significantly different at $p<0.05$.

Table 7: Vitamin A and mineral content of moringa leaf extract (g/100g dry matter content)

Product	pH	TTA%	TTSS^{o}Brix	Vit A mg/100g	Calcium mg/100g	Iron mg/100g	Zinc mg/100g

M.L. E	5.91±0.04[c]	0.18±0.004[c]	3.07±0.06[a]	11.42±0.84[b]	910.18±15.90[c]	90.26±1.80c	28.88±1.25[b]
P-Value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

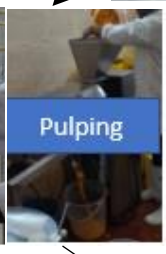
Values are means ± SD. Means with different superscript letters along the columns are significantly different at $p<0.05$.

Table 8: phytochemical characteristics of moringa leaf extract

Product	Total phenolics mg GAE/100g D. W	Flavonoids mg QE/100g DW
M.L. E	12787.3	8025.1
P-Value	<0.0001	<0.0001

Values are means ± SD. Means with different superscript letters along the columns are significantly different at $p<0.05$.

SOME PICTURES DEPICTING THE ALL MANGO-MORINGA NECTAR PROCESS



Blending with determined ratio of mango pulp and moringa leave extract+sugar+citric acid stabilizer and preservative

Pasteurization at 70^0C for 10 min

Hot filling at 55^0C