Bindura University of Science Education

Protocol development and preservation of masau-flavored maheu.

BY

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Approval form

The undersigned certify that they have read the dissertation “Protocol development and preservation of masau-flavored maheu” and it is suitable for submission to the Biological Sciences Department, Faculty of Science and Engineering for assessment.

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Signature of Chairperson of Department: Date: 17/08/25

Declaration

I, Kudakwashe Matito B201371B, declare that this research project herein is my work and has not been plagiarized from any source(s) without acknowledgement of the concerned author(s) either electronically or otherwise.

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I, Dr. P. Jinga, declare that I have supervised this thesis and I am satisfied that it can be submitted to the Biological Sciences Department, Faculty of Science and Engineering, at Bindura University of Science Education.

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Dedication

I dedicate this research project to my loving parents, whose unwavering support, sacrifices, and encouragement have been the foundation of my journey; to my siblings, for their constant motivation and companionship; to my classmates, for their collaboration, shared efforts, and inspiration throughout the course; and to my lecturers, whose guidance, knowledge, and dedication have been invaluable in shaping this work.

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Abstract

This study is aimed to develop and preserve a novel, nutritious beverage by blending Masau (*Ziziphus mauritiana*) fruit with Maheu, a traditional fermented cereal drink widely consumed in Zimbabwe. Masau, rich in essential micronutrients such as vitamin A and C, potassium, fiber, and antioxidants, was incorporated into Maheu to enhance its nutritional profile and address local micronutrient deficiencies. The research established a production protocol and optimized pasteurization conditions to improve shelf life and product stability. Dried Masau fruits were processed to extract both juice and pulp, which were evaluated for flavoring potential. Maheu was prepared using sieved maize meal and fermented with sorghum malt for 48 hours. Sugar concentration trials (5g, 10g, and 15g per 100ml) indicated that 10g/100ml was most preferred based on a 5-point hedonic scale, balancing sweetness without overpowering Maheu's natural flavor. Flavoring experiments showed that Masau juice at 100ml per 100ml of Maheu was most preferred, offering strong flavor, good texture, and acceptable thickness, while pulp-based flavoring was less favored due to inconsistent texture. To determine the best preservation method, pasteurization experiments were conducted at various temperatures (60°C–90°C for 15 seconds) and times (5–20 seconds at 80°C). Shelf-life assessments were based on pH changes and sensory evaluations over a 21-day refrigerated storage period. The results revealed that pasteurizing at 80°C for 15–20 seconds provided optimal preservation, maintaining higher pH values (3.9–4.0), indicating reduced microbial activity. Sensory evaluations using a 9-point hedonic scale also favored these conditions above, with high scores for color, taste, and texture. Strong positive correlations were observed between both pasteurization temperature and time with final pH, confirming their significant influence on microbial stability. This research demonstrates the potential for producing a shelf-stable, Masau-flavored Maheu beverage that is nutritious, locally sourced, and well-suited to the Zimbabwean market. The established production and preservation protocols support value addition, nutritional enhancement, and contribute to local food security efforts.

Contents

Chapter 1

Introduction

1.1 Background

Indian berries (masau) are nutritious fruits that are found in very arid regions. The tree originated from India and it is drought resistant. Their trees are able to produce a large biomass even if there is a drought. They are widely known as *Ziziphus mauritiana* (scientific name). Masau are common in Zimbabwe but not indigenous. They are in abundance in Muzarabani down the Zambezi valley. The Masau fruit is nutritious because it contains most important nutrients such as vitamin A and C, potassium (K) and they are a source of fiber. The fruit also plays a big role in maintaining human body health since it contains antioxidants (Nyanga, 2014) .Masawu fruits have got a sweet -Sower taste and a very wonderful smell which makes them appetizing to eat . Due to the nutritious importance and good taste of the Masawu fruits, they may be blended with maheu to form a much more nutritious and healthier beverage (Masau-flavored maheu).

Maheu is a fermented cereal beverage produced in Zimbabwe. Maheu is known for its high nutritional value. Maheu is mostly used to feed the sick or young children since it is easy to swallow and a source of energy. It is made by either using maize meal flour, millet or other grain meal flour which is rich in starch. the beverage is fermented using a malt which is the provider of the amylase enzyme. Amylase enzyme is responsible for breaking down starch into sugar. The nutritional content of Maheu include high levels of carbohydrates, calcium and folic acid which are good for human health, as well as low levels of sodium (which may increase blood pressure) and low saturated fats(cholesterol) (Olusanya, 2018). Combining both the Masau fruit and Maheu beverage will make the novel Masau-flavored maheu drink very nutritious as well as healthy and recommended food. The aim of producing this product is to improve human healthy, increase nutritional status in humans as well as to ensure food security in Zimbabwe. In order to meet this aim, the Masawu flavored mahewu product needs to be standardized and well preserved for a better shelf life. The most appropriate and effective preservative method has not been found yet for this beverage, so a comparative study of preservative methods has to be done so as to determine the most effective preservative method for the Masau maheu beverage

Food preservatives are substances or physical methods that prevents spoilage of food caused by microbial growth or undesired chemical changes. Food preservatives target the microorganisms in the food and stops their activities by either killing them or providing an environment which is not conducive for their growth. Preservatives are categorized into chemical and physical or mechanical methods. Chemical preservatives consist of chemicals such potassium sorbet, sodium benzoate and citric acid. Each chemical preservatives have got its own target microorganism that is, they are specific, for example potassium sorbet target only bacteria leaving fungi. Physical or mechanical preservatives are methods making an environmental condition tough for the survival of microorganisms without the use of chemicals, for example pasteurization and freezing. the physical preservatives are not specific i.e. they destroy every microorganism. Physical methods of preservation are the most effective because they target all the living microorganisms in the food i.e. they are not specific (Rahman, 2020). Chemical methods are associated with diseases such as cancer if consumed in excess as well as heated but rather they are effective since they are specific. Physical preservative methods may be responsible for the loss of sensory qualities of food. Basing on these arguments a comparative study of different preservative methods has to be carried out so as to determine the best method to preserve the novel masau-flavored maheu.

1.2 Problem statement

If Masau and maheu are blended, a nutritious, locally sourced beverage that addresses the micronutrient deficiency in Zimbabwe can be made.

There are no Masau flavored Maheu that are being produced commercially in Zimbabwe. when developed, they need a standard preservation method to extend their shelf life.

1.3 Aim

The aim of this study was to develop production protocol for the Masau-flavored.

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The objectives of this study were to:

(i)Determining the quantity of ingredients for masau flavored maheu.

(ii)Determine the optimum temperature for pasteurizing masau-flavored maheu (preservation)

(iii)Determine the optimum time for pasteurization.

1.5 Research Questions

(1) What are the quantities required for the production of masau-flavored maheu.

(2) What is the optimum pasteurizing temperature for masau-flavored maheu?

(3) What is the optimum time period of pasteurization for masau-flavored maheu?

1.6 Justification

This study is significant because it determines the production protocol for Masau-flavored maheu and evaluate the effect of pasteurization. This study is important for nutrition in Zimbabwe. The study is also important to avoid spoilage of the beverage.

1.7 Limitations

A pasteurizer was desirable but it was unavailable, a water bath and a stop watch were used instead.

1.8 Delimitation

This study is focused on the use of Masawu juice and pulp as a flavoring agent and micronutrient donor, excluding other potential flavorings or ingredients.

Chapter 2

Literature review

2.1 Origins, History and Innovations of Maheu

Maheu is a traditional fermented cereal beverage that originated in Southern Africa, particularly in Zimbabwe, South Africa, and Botswana. The drink has been consumed for centuries. Maheu is typically made from fermented sorghum or maize meal. The preparation process of mahewu by (Pswarai & Ganzela ,2019) involves the following stages:

The meal is sieved to remove any lumps or large particles. The meal is mixed with water in a large container to create a uniform paste. The paste is boiled to form maize porridge Fermentation – malt is added as the fermentation agent and fermentation is allowed to proceed for 2-3 days.

Maheu, has undergone significant transformations over the years. From its humble beginnings as a simple fermented corn drink to the various innovations and variations that exist today, Maheu has demonstrated its versatility and adaptability.

Traditionally, Maheu was brewed using cornmeal, water, and a starter culture. However, over time, brewers have experimented with different ingredients and flavors, resulting in various traditional variations. For instance, some brewers add herbs and spices, such as ginger, garlic, or chili peppers, to give Maheu a unique flavor. Others add fruits like mango, banana, or papaya to create a sweeter and more refreshing drink. Additionally, some brewers use sorghum or millet instead of corn to create a different flavor profile. These traditional variations demonstrate the creativity and resourcefulness of Maheu brewers.

Modern innovations have transformed Maheu into a more commercial and appealing product. Flavored Maheu, for example, has become increasingly popular, with flavors like strawberry, orange, or lemon being added to the traditional brew. Chibuku beer, which combines the traditional fermented corn drink with modern brewing techniques, has also gained popularity. Furthermore, Maheu powder, and Maheu energy drink have been developed, catering to a wider range of consumers. These modern innovations have not only increased the appeal of Maheu but have also created new business opportunities for entrepreneurs.

The variations and innovations of Maheu demonstrate the versatility and adaptability of this traditional fermented corn drink. From traditional variations to modern innovations and experimental variations, Maheu has shown its potential for commercialization and modernization. As the demand for traditional and artisanal products continues to grow, Maheu is well-positioned to capitalize on this trend, providing a unique and authentic African experience for consumers around the world.

Figure 1: 4 Different flavored mahewu produced by Dairybord Zimbabwe

2.2 The Significance of Maheu in Zimbabwean Society

Maheu, has been an integral part of the country's culture and heritage for centuries. This beverage holds significant cultural value, playing a vital role in social gatherings, ceremonies, and daily life.

Firstly, Maheu plays a crucial role in social bonding and community building. In Zimbabwean culture, sharing Maheu is a symbol of hospitality and friendship. During social gatherings, such as weddings, funerals, and harvest celebrations, Maheu is often served as a sign of respect and unity. This communal consumption of Maheu strengthens social bonds, fostering a sense of community and togetherness (Olusanya, 2018). Furthermore, the preparation and sharing of Maheu provide opportunities for social interaction, storytelling, and cultural exchange.

Maheu is also a symbol of Zimbabwean cultural identity. The preparation and consumption of Maheu are deeply rooted in traditional practices and customs. The fermentation process, which involves mixing cornmeal with water and allowing it to ferment, is a time-honored tradition passed down through generations. Maheu is often served in traditional clay pots, adding to its cultural significance. This beverage has become an integral part of Zimbabwean heritage, reflecting the country's history, traditions, and values.

Maheu also holds significant nutritional value. The fermentation process increases the bioavailability of nutrients, making Maheu a valuable component of the traditional Zimbabwean diet (Magoderwa K, 2022). Rich in vitamins, minerals, and antioxidants, Maheu provides essential nutrients for maintaining good health. Furthermore, Maheu is often consumed as a refreshing beverage, providing hydration and energy.

Maheu also plays a vital role in the local economy. Maheu production and trade provide income opportunities for farmers, brewers, and vendors. The commercialization of Maheu production has also led to the growth of small-scale enterprises, contributing to the country's economic development. However, the commercialization of Maheu production has also raised concerns about the loss of traditional brewing methods and the homogenization of cultural practices.

2.3 Microbiology of Maheu Fermentation

Maheu fermentation primarily involves lactic acid bacteria (LAB), such as *Lactobacillus plantarum*, *Lactobacillus brevis*, and *Pediococcus pentosaceus*. These bacteria are key to fermenting the sugars in sorghum or maize meal, producing lactic acid and lowering the pH of the mixture (Mgwada T, 2018). Yeasts, including *Saccharomyces cerevisiae* and various *Candida* species, may also be present and contribute to the fermentation process. Molds like *Aspergillus* and *Fusarium* species may appear, although their specific role in fermentation remains unclear.

The process starts when the sorghum or maize meal is inoculated with LAB and other microorganisms. As LAB metabolize the sugars, lactic acid is produced, resulting in a drop in pH. This acidic environment promotes the growth of LAB while suppressing unwanted microbial growth. Yeasts and other microbes may also generate carbon dioxide, which can give the mixture a fizzy texture.

Various factors influence the fermentation process, such as temperature, pH, water activity, and potential contamination. LAB thrive best at temperatures between 25°C and 30°C, with an optimal pH range of 4.5 to 5.5. Water activity levels between 0.95 and 0.99 are also ideal for microbial growth. Contamination by undesirable microorganisms can negatively impact the fermentation and compromise the quality of the final product.

Pathogenic bacteria like *Escherichia coli* and *Salmonella* can contaminate Maheu, posing health risks. Additionally, certain molds can produce harmful mycotoxins (Magoderwa K, 2022). Therefore, maintaining good manufacturing practices and strict hygiene is crucial to ensure Maheu is safe for consumption.

2.5 Masau Fruit

Figure 2: Dried *Ziziphus mauritiana (*Masau)

The Masau fruit, commonly known as the Indian jujube, is a tropical fruit originally from Asia. This small, reddish-brown fruit has been used for centuries in traditional medicine and cooking, and its rich nutritional content and health benefits make it a valuable part of a healthy diet.

One of the key benefits of the Masau fruit is its impressive nutrient composition. It provides high levels of vitamins A, C, and K, along with essential minerals such as potassium, magnesium, and iron. It also contains a variety of antioxidants, including flavonoids, phenolic acids, and ascorbic acid, which help protect the body's cells from oxidative stress caused by free radicals. Furthermore, Masau is a good source of both soluble and insoluble dietary fiber, which supports digestive health.

The fruit may also contribute to better cardiovascular health. Its high potassium content can help lower blood pressure by balancing sodium levels and supporting the health and function of blood vessels. In addition, the antioxidants and polyphenols in Masau may reduce inflammation and help relieve symptoms related to inflammatory conditions such as arthritis.

2.6 Traditional Processing of Masawu

Traditionally, Masawu was used to make alcoholic beverages which were used in ceremonial celebrations and sold in local bars (Nyanga, 2014). The alcoholic beverages are called Kachasu in Shona .it is mainly produced in muzarabani. the traditional production involves the fermentation of Masawu and fractional distillation. Kachasu is so intoxicating and it damages the liver. Kachasu it was banned in 1971. The production of Kachasu is now private and is done by certain families in rural areas for income generation.

Figure 3 : Fermented-Masau for the production of Kachasu

Figure 4: Fractional distillation of Masau to produce Kachasu

2.7 Pasteurization

Pasteurization is a widely utilized method of food preservation, particularly in the dairy and beverage industries, that involves the application of mild heat to destroy pathogenic microorganisms and extend shelf life without significantly altering the food's quality (Jay et al., 2005). The technique was first developed by Louis Pasteur in the 19th century to prevent spoilage in wine and beer, and has since become an essential component of modern food safety protocols (Lechevalier & Solotorovsky, 2018).

There are several types of pasteurization processes, including low-temperature long-time (LTLT), high-temperature short-time (HTST), and ultra-high temperature (UHT) treatments. Each method is specific to specific food products and safety requirements. HTST, for example, is commonly used in milk processing and involves heating milk to 72°C for 15 seconds, effectively reducing the microbial load while retaining the product's nutritional and sensory attributes (Lewis & Heppell, 2019).

Research has consistently shown that pasteurization is effective in reducing the risk of foodborne illnesses caused by pathogens such as *Listeria monocytogenes, Salmonella,* and *Escherichia coli*. According to Doyle and Buchanan (2013), thermal processing through pasteurization significantly lowers the microbial content, thereby minimizing the risk of infection and spoilage. However, the process is not intended to sterilize food but to reduce pathogenic microorganisms to safe levels (Jay et al., 2005).

While the benefits of pasteurization in public health are widely acknowledged, some studies have raised concerns about its impact on nutritional quality. For instance, Deeth and Datta (2011) argue that although vitamin losses are minimal in HTST treatments, certain heat-sensitive compounds such as vitamin C and some enzymes may be degraded during UHT processing. Nevertheless, the trade-off is generally considered acceptable given the substantial reduction in microbial risks.

In addition to dairy, pasteurization has found applications in other industries, including fruit juices, liquid eggs, and canned foods. The Food and Agriculture Organization (FAO, 2004) highlights pasteurization as a key intervention in global food safety strategies, particularly in developing countries where refrigeration and cold chain logistics may be limited.

Emerging technologies are also influencing pasteurization methods. Non-thermal alternatives like high-pressure processing (HPP) and pulsed electric fields (PEF) are being explored for their potential to inactivate pathogens while better preserving nutritional and sensory qualities (Huang et al., 2017). These methods offer promising avenues for innovation but require further validation and regulatory approval.

2.8 Incorporating Masau into Maheu

Incorporation masau into maheu can improve the sensory appeal (taste, aroma, color), enhance the nutritional value (especially antioxidant capacity and vitamin C content) and extend the shelf life due to natural antimicrobial compounds in masau.

Fruit enhanced fermented beverages showed increased consumer acceptance compared to traditional varieties.

2.9 Masau-Flavored Maheu

When Masau and maheu are blended, a nutritious, locally sourced beverage that addresses the micronutrient deficiency in Zimbabwe can be made.

There are no Masau flavored Maheu that are being produced commercially in Zimbabwe. Producing this beverage commercially is the best idea because statics shows that food with natural fruits are now scarce in the market, therefore this beverage is an addition to the natural foods.

Chapter 3

Materials and methods

3.1 Masau Juice Extraction

1kg Dried masau fruits were used. 5L of distilled water was boiled. Masau fruits was then added to the boiling water and boiled for 30 minutes. The boiled fruits were crushed to separate the seeds and the pulp (**Figure 5**).

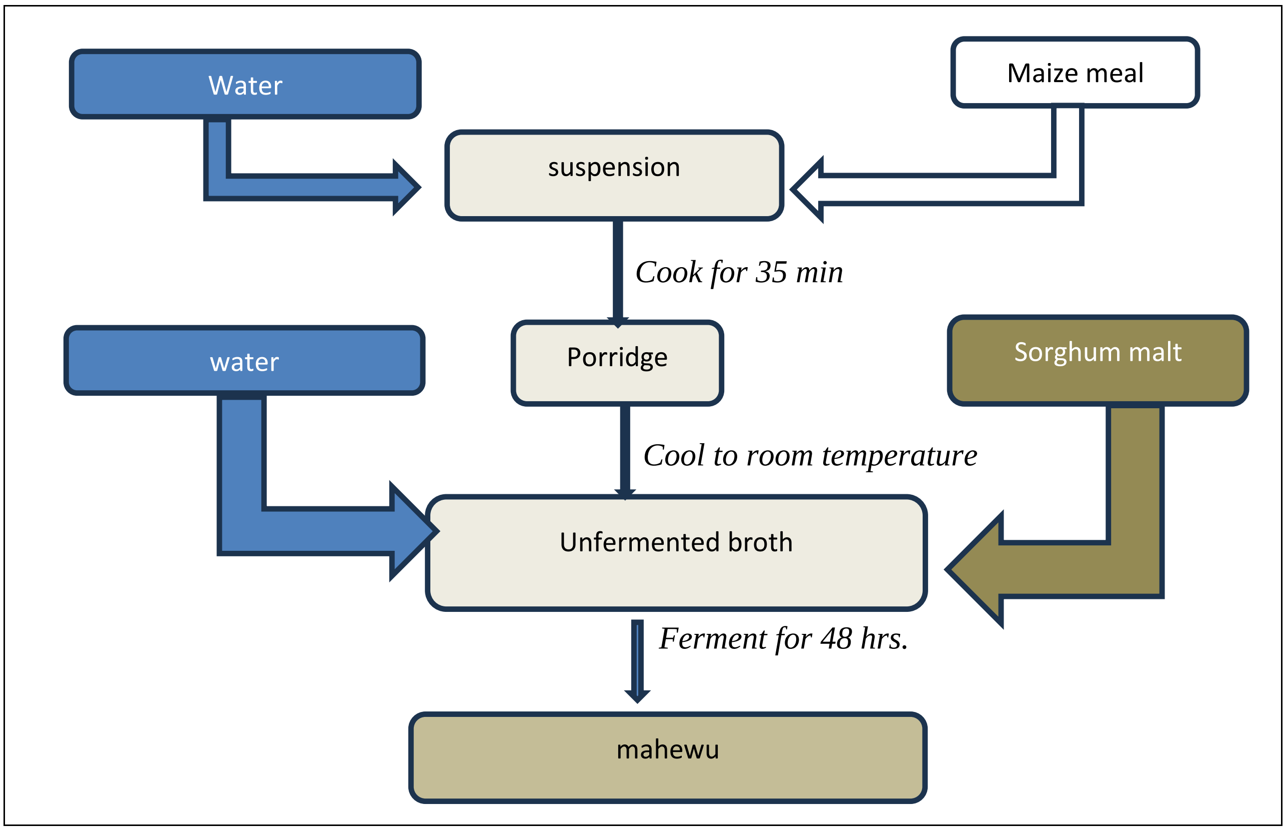
Different sizes of sieves (58 nm, 45 nm, 38 nm and 25 nm) aperture were used to separate solid material from juice. The juice was left to cool. The juice was made as per BUSE innovation hub protocol.

Figure 5: Sieving of masau juice

3.2 Plain Maheu Cooking

Maheu was produced using the modified method described by Ganzlea (2019), which employs a maize meal to water ratio of 8g to 100ml. Initially, maize meal was sieved using a 100-micron sieve to obtain 240g of fine maize meal. This fine maize meal was gradually added to 3 liters of warm water while stirring continuously. Stirring continued until the mixture reached boiling point. Once boiling, the mixture was allowed to boil for 35 minutes, with stirring occurring at 5-minute intervals throughout the boiling process. After boiling, the porridge was left to cool for 3 minutes. It was then allowed to stand undisturbed for 2 hours.

3.3 Fermentation of Maheu:



After the porridge had cooled, 2 liters of distilled water were added to the solidified mixture, followed by thorough stirring to ensure homogeneity. 20 grams of sorghum malt were incorporated into 5 liters of the prepared Maheu, with continued stirring. The mixture was then transferred into a closed beaker and left to ferment for two days.

3.4 Sugaring

Sugaring experiments were carried out in order to determine the best amount for Masau flavored Maheu. Three different concentrations of sugar (5g,10g and 25g per 100ml) were added to three samples of plain Maheu **(Figure 6, Table 1).**

The samples were presented to 12 members (6 food laboratory staff and 6 random people) for feedback on sweetness. Respondents were asked to give a comment on the sweetness guided by these criteria (too sweet, good, not good/ add more)

Table 1: Amount of sugar added to 100ml of plain Maheu.

Sample Name	Amount of plain maheu (ml)	Amount of sugar added(g)
Control	100	0
A1	100	5
A2	100	10
A3	100	15

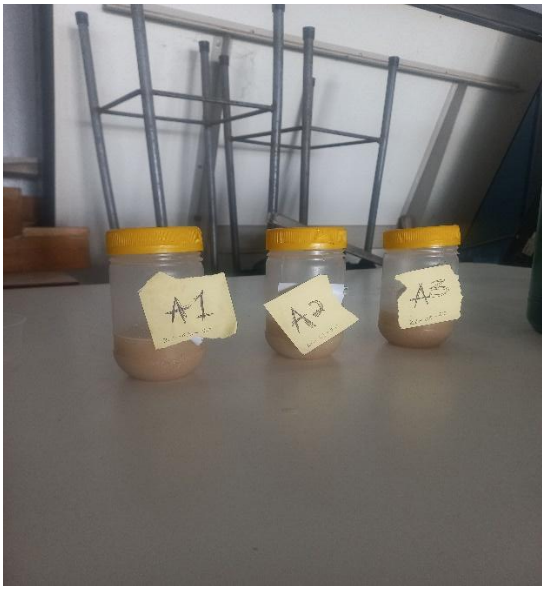


Figure 6: Bottles of prepared sugar samples

3.5 Flavoring Maheu with Masau Palp(paste) and Masau juice

Flavoring experiments were carried out in order to determine which of the flavorings of masau **(fig 3.3**) was best for flavoring Maheu. Each flavoring was added to 100ml of premade plain maheu at three different concentrations as shown by **Fig 8, Table 2, Fig 9** and **Table 3.** The samples were presented to 12 Laboratory staff members for feedback on flavor intensity, texture and thickness. Plain Maheu was used as a control. Respondents were required to give a comment on each criteria using the following key:

(i)Flavor intensity – weak, minimum and strong

(ii)Thickness - fine, medium and thick

(iii)Texture - bad, neutral and good

3.5.1 Types of Flavors

A B

Figure 7: A – Masau juice flavor and B – masau paste flavor

3.6 Flavoring Experiments

3.6.1 Flavor A (masau juice)

3 different concentration of flavor A (masau juice) were added to 100ml of premade plain maheu **Figure 8** and **Table 2.**

Figure 8: Flavor A samples

Table 2: The amount of flavoring A (Masau juice) added to each 100ml sample of plain Maheu.

Sample name	Plain Maheu (ml)	Amount of flavoring added (ml)
Control	100	0
B1	100	25
B2	100	50
B3	100	100

3.6.2 Flavoring B (Masau paste)

3 different concentration of flavor B (masau pulp/paste) were added to 100ml of premade plain maheu **Figure 9** and **Table 3.**

Figure 9: Flavor B samples

Table 3: The amount of flavoring B (Masau paste) added to each 100ml sample of plain Maheu.

Sample Name	Plain Maheu (ml)	Amount of flavoring added (ml)
Control	100	0
C1	100	25
C2	100	50
C3	100	100

3.7 Determining Optimum Pasteurization Temperature on the Shelf Life of Masau-Flavored Maheu

This experiment was done to investigate the effect of different pasteurization temperatures on the shelf life of Masau-flavored maheu and determine the optimum pasteurization temperature that can preserve masau-flavored maheu for long.

Pasteurization temperature was the independent variable, Fixed Parameter was Pasteurization time 15 seconds and Temperatures Tested were 60°C, 70°C, 80°C, and 90°C.

3.7.1 Procedure:

A total of 500 ml of Masau-flavored maheu was prepared and aseptically portioned into five sterile bottles, with each bottle containing 100 ml of the beverage. Each bottle was labeled based on the temperature at which it would undergo pasteurization. Pasteurization was carried out using a water bath set to the designated temperatures of 60°C, 70°C, 80°C, and 90°C, with each sample held at its respective temperature for 15 seconds. After pasteurization, all samples were rapidly cooled in an ice bath. Once cooled, the samples were transferred into sterile containers and stored under refrigerated conditions waiting for microbiological analysis.

3.7.2 Shelf-Life Evaluation:

Shelf life was assessed over 21 days storage period by monitoring changes in pH and conducting sensory evaluations.

On pH Measurement a calibrated digital pH meter was used to measure the acidity of each sample at 7-day intervals during refrigerated storage.

On Sensory Evaluation a semi-trained sensory panel of 12 people evaluated the samples at regular intervals for attributes such as color, aroma, taste, and overall acceptability using a 9-point hedonic scale. Evaluations were conducted under controlled conditions.

3.8 Effect of Pasteurization Time on the Shelf Life of Masau-Flavored Maheu

Following the identification of 80°C as the optimal pasteurization temperature in Section 3.8, a second experiment was conducted to examine the effect of varying pasteurization durations on product shelf life.

Independent Variable: Pasteurization time
Fixed Parameter: Pasteurization temperature – 80°C
Time Intervals Tested: 5 seconds, 10 seconds, 15 seconds, and 20 seconds

3.8.1 Procedure

A fresh batch of Masau-flavored maheu was prepared and aseptically divided into five sterile 350 ml bottles, with each bottle containing 100 ml of the beverage. The bottles were labeled according to the intended duration of pasteurization. Pasteurization was carried out in a water bath at a constant temperature of 80°C for varying time intervals of 5, 10, 15, and 20 seconds. After heat treatment, the samples were rapidly cooled in an ice bath. The pasteurized maheu samples were transferred into sterile containers and stored at 4°C in a refrigerator until further analysis.

3.8.2 Shelf- Life Evaluation but measuring pH and sensory quality test

a b

Figure 10: a- measuring pH using digital pH meter on day 7. **b**- digital pH meter reading

Shelf -life evaluation of the Masau-flavored maheu was conducted using both physicochemical and sensory parameters during refrigerated storage. pH measurements were carried out at 7-day intervals to monitor pH changes indicative of microbial activity and potential spoilage (**Fig 10**).

Sensory evaluation was performed by a panel of 12 individuals, including laboratory staff, using a 9-point hedonic scale to assess key quality attributes such as appearance, aroma, taste, and overall acceptability. All evaluations were conducted at consistent storage intervals under standardized conditions to ensure reliability and comparability of results throughout the study period.

Chapter 4

Results

4.1 Sugar Concentration Preferences

A total of 12 staff members evaluated sweetness using a qualitative feedback system. The results (**Table 4**) showed that Sample A2 (10g sugar/100ml**)** was most preferred, receiving the highest number of "good" ratings. The acceptability of sugar concentration was tested using three different levels: 5g, 10g, and 15g per 100ml of plain Maheu. Feedback was gathered from 12 laboratory staff based on a three-tiered scale: "too sweet," "good," and "not good/add more".

Table 4.: Sensory evaluation of sweetness for different sugar concentrations

Sample	Sugar Added (g/100ml)	Sweetness Feedback
Control	0	Not good (11/12)
A1	5	Not sweet enough (9/12)
A2	10	Good (all respondents)
A3	15	Too sweet (10/12)

The graph below illustrates the avarage scoring feedback of 12 respondants on sugar concentration preferences. A 5point hedonic scale was used to rate the sweetness of each sample, with 5 being the best preferred and other lower ratings showing lower preferences.

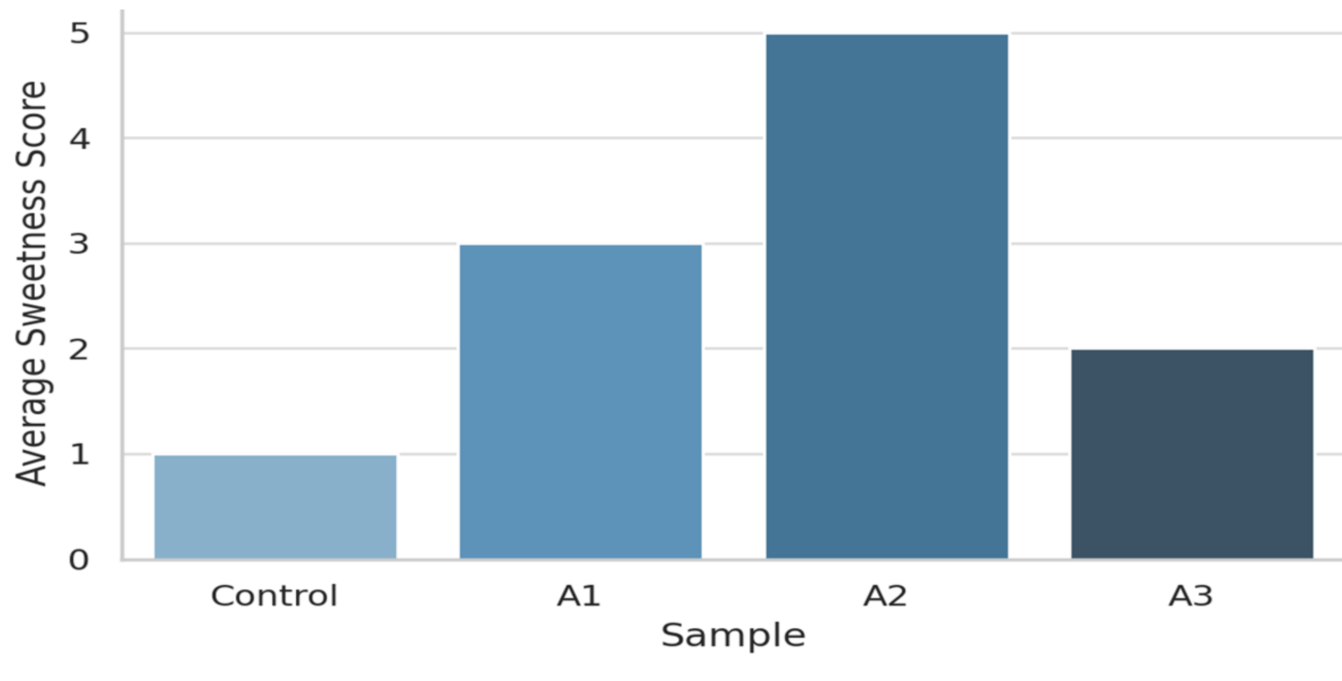


Figure 11: Average sweetness preference scores for different sugar concentrations of maheu samples.

Therefore, the sampleA2 (10g/100ml sugar concentration) was the most preferred. It balanced sweetness without overwhelming the Maheu's natural flavor profile. Over-sweetening at 15g compromised taste for many, while 5g was insufficient to enhance flavor.

4.2 Flavoring Preference

4.2.1 Flavor A (Masau Juice)

Table 5 shows responses from sensory evaluations on flavor intensity, texture, and thickness. Sample B3 (100 ml Masau juice) was rated highest in all categories.

Table 5: Evaluation of Flavor A (Masau Juice) Concentrations

Samples	Flavor Added (ml)	Flavor Intensity	texture	Thickness
Control	0	No intensity	No texture	No thickness
B1	25	Weak	Neutral	Fine
B2	50	Minimum	Good	Medium
B3	100	Strong	Good	Good

4.2.2 Flavor B (Masau Paste)

Flavor B (paste) had acceptable texture but was reported to be too thick at higher concentrations. C3 was intense but less favorable than the juice equivalent.

Table 6: Flavor B sensory evaluation feedback (Masau Paste)

Sample	Flavor Added (ml)	Flavor Intensity	Texture	Thickness
Control	0	Weak	Neutral	Fine
C1	25	Weak	Neutral	Fine
C2	50	Minimum	Neutral	Medium
C3	100	Strong	Mixed	Thick

Flavor A (Masau juice) at 100ml per 100ml of Maheu was most preferred, with 10 out of 12 people preferred it. According to respondents, it provided a strong flavor, a good texture, and suitable thickness. Flavor B was less preferred with two people preferring it, especially at higher concentrations, due to texture inconsistencies.

4.3 Determination of Optimum Pasteurization Temperature

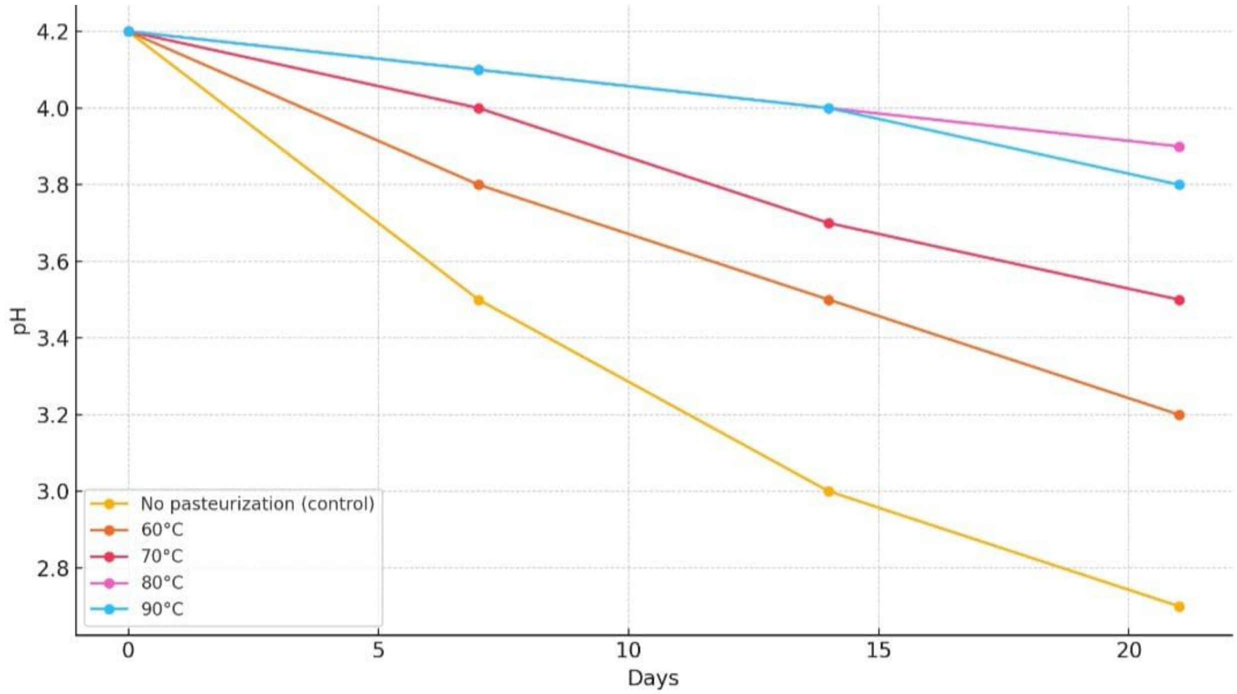
4.3.1 Determination of the Best Pasteurization Temperature for Masau-Flavored Maheu.

pH and sensory evaluations were monitored over 21 days. 80°C pasteurization yielded the most stable pH and highest sensory acceptability (**Table 7**)

Table 7: pH Values of Samples at Different Pasteurization Temperatures

Temp (°C)	Day 0	Day 7	Day 14	Day 21	Sensory Score (Day 21)
No pasteurization	4.2	3.5	3.0	2.7	3.8
60	4.2	3.8	3.2	3.0	5.0
70	4.2	3.9	3.4	3.2	6.5
80	4.2	4.1	4.0	3.9	8.3
90	4.2	4.0	3.8	3.5	6.0

The graph below illustrates the pH changes over 21 days for samples pasteurized at various temperatures.



The graph shows that 80°C was the best temperature because the sample pasteurized at 80°C was able to maintain a low pH drop and this shows that there was less microbial activity.

4.3.2 Correlation Analysis

There is a negative relationship between time (days**)** and pH for each pasteurization temperature. The Pearson correlation coefficient for each sample is shown in table 8

Table 8: Time vs pH for Each Sample

Temperature (°C)	**Correlation (r)**
No pasteurization	-0.999
60	-0.998
70	-0.998
80	-1.000
90	-0.999

All samples show a strong negative correlation between time and pH, indicating pH drops with storage. 80°C had the most stable pH, indicated by its linear and moderate decline (r = -1.000), This confirms 80°C as the optimal pasteurization temperature for extending shelf life and maintaining product quality.

4.3.3: Sensory Evaluation of Masau-Flavored Maheu at Different Pasteurization Temperatures

Table 9: Sensory Evaluation of Masau-Flavored Maheu at Different Pasteurization Temperatures

Temperature (°C)	Appearance (Mean ± SD)	Aroma (Mean ± SD)	Taste (Mean ± SD)	Overall Acceptability (Mean ± SD)
No pasteurization	2	2	4	4
60	5.2 ± 0.6	5.0 ± 0.8	4.8 ± 0.9	5.0 ± 0.7
70	6.0 ± 0.7	6.3 ± 0.5	6.5 ± 0.4	6.5 ± 0.6
80	8.5 ± 0.4	8.0 ± 0.6	8.3 ± 0.5	8.3 ± 0.4
90	6.8 ± 0.5	6.5 ± 0.6	6.2 ± 0.7	6.0 ± 0.6

Based on **table 9**, 80 is the optimum temperature because it has got high overall acceptability.

4.4 Determination of Pasteurization Time on Masau Flavored Maheu.

4.4.1: pH Change Over Time on Varying Pasteurization Times at 80°C

pH values decrease after 21 days as shown in **Table 10** with respect to pasteurization time. Some samples showed rapid pH decrease than others due to pasteurization time differences. This shows that samples with rapid pH decreases have got more microbial activities which results in spoilage.

Table 10: pH Change Over Time on varying pasteurization times at 80°C

Time (sec)	Day 0	Day 7	Day 14	Day 21	Sensory Score (Day 21)
No pasteurization	4.2	3.5	3.3	2.8	2.1
5	4.2	3.9	3.6	3.4	6.0
10	4.2	4.0	3.8	3.5	7.2
15	4.2	4.1	4.0	3.9	8.3
20	4.2	4.1	4.0	3.9	8.4

4.4.2 Correlation Analysis

There is a negative relationship between time (days**)** and pH for each pasteurization time. The Pearson correlation coefficient for each sample is shown in table 11

Table 11: Correlation (Time vs pH) for Each Sample

Pasteurization Time (sec)	**Correlation (r)**
No pasteurization	-0.998
5	-0.997
10	-0.997
15	-1.000
20	-1.000

Therefore:

All samples show a strong negative correlation between time and pH. Longer pasteurization times (15s and 20s) maintained a slower rate of pH decline, suggesting better microbial stability over time.

4.4.3 Sensory Evaluation on Pasteurization Time

A 9point hedonic scale was used to evaluate sensory attributes: color, taste, and texture. The averaged results are shown in **table 12**.

Table 12: Sensory Evaluation of Masau-Flavored Maheu at 80°C for Varying Pasteurization Times

Time (seconds)	Appearance (Mean ± SD)	Aroma (Mean ± SD)	Taste (Mean ± SD)	Overall-Acceptability (Mean ± SD)
No pasteurization	2	4	2	4
5	6.2 ± 0.5	6.0 ± 0.6	5.8 ± 0.7	6.0 ± 0.5
10	7.2 ± 0.6	7.1 ± 0.5	7.2 ± 0.6	7.2 ± 0.6
15	8.5 ± 0.3	8.0 ± 0.4	8.4 ± 0.3	8.3 ± 0.4
20	8.4 ± 0.4	8.1 ± 0.5	8.5 ± 0.3	8.4 ± 0.4

Therefore, both of pasteurization results shows that Optimal Temperature is 80°C and Optimal Time is 15–20 seconds, Statistical Evidence shows that both temperature and time significantly influence the product's physicochemical stability over 21 days.

Chapter 5

5.1 Discussion

The primary objective of this study was to optimize the formulation and processing conditions of Masau-flavored Maheu by assessing sugar concentration preferences, flavoring types and concentrations, and the impact of pasteurization temperature and time on shelf life and sensory quality. The results reveal critical insights into consumer acceptability and product stability, which are vital for the commercial viability of this traditional fermented beverage.

5.1.1 Sugar Concentration Preferences

The findings indicate that a sugar concentration of 10g/100ml is the most acceptable among panelists. This level achieved a balance between sweetness and the inherent flavor of Maheu, avoiding the sour taste at 5g and the excessive sweetness at 15g. This result aligns with previous studies indicating that moderate sugar levels enhance the palatability of fermented cereal beverages without overwhelming the natural flavors (Chavan and Kadam, 2023). The inclusion of added sugar in food and beverage products such as flavored Maheu can have both positive and negative consequences. On the positive side, sugar significantly enhances the palatability of food by improving taste, masking bitterness or sourness, and increasing overall consumer acceptance particularly important when introducing nutrient-rich but potentially less appealing ingredients like Masau. Enhanced flavor is especially beneficial in populations such as children or individuals with limited appetite. Furthermore, sugar serves as a quick source of energy, which can be advantageous in populations suffering from undernutrition or needing rapid energy replenishment. It also acts as a preservative by reducing microbial growth in liquid products, thereby extending shelf life and improving product stability (Jay, 2000; FAO, 2016; Drewnowski and Almiron-Roig, 2010). However, the negative health consequences of excessive added sugar are well-documented and pose serious public health concerns. High intake of added sugars, especially from sugar-sweetened beverages, is strongly associated with an increased risk of obesity, metabolic syndrome, and type 2 diabetes (Malik et al., 2010; Stanhope, 2016). The World Health Organization (2015) recommends that free sugar intake be limited to less than 10% of total energy, with a further reduction to below 5% for additional health benefits. Moreover, regular consumption of sugary drinks contributes to dental caries, particularly when consumed frequently or outside of meals (Moynihan and Kelly, 2014). There is also growing evidence linking high sugar intake to cardiovascular disease, with one study showing that individuals who consume more than 10% of their daily calories from added sugars have a significantly increased risk of heart disease (Yang et al., 2014).

In light of these findings, it is essential that product developers strike a balance between sensory appeal and nutritional safety. While sugar may be necessary to improve the acceptability of functional beverages like flavored Maheu, its inclusion should be carefully moderated. Alternatives such as natural non-nutritive sweeteners or fruit-based sweetening agents can be considered to reduce added sugar content without compromising taste. Additionally, clear labeling and consumer education about sugar content can empower individuals to make healthier dietary choices.

5.1.2 Flavoring Preferences

The use of Masau juice at 100ml per 100ml of Maheu yielded the best sensory performance in terms of flavor intensity, texture, and overall mouthfeel. In contrast, the paste form produced inconsistent textures, especially at higher concentrations. These findings underscore the importance of ingredient form and solubility in achieving consumer-preferred sensory profiles (Murevanhema and Jideani, 2013). Flavor preference plays a critical role in determining the market success of food and beverage products, directly influencing consumer acceptance, repeat purchases, and ultimately sales volumes. In highly competitive markets—particularly those involving traditional or functional beverages like Maheu—getting the flavor profile right can make the difference between commercial success and failure. Consumers tend to make purchase decisions based on sensory attributes, with flavor often being the most influential factor, even above nutrition or brand loyalty (Tuorila and Monteleone, 2009).

A product that aligns with consumer taste preferences is more likely to elicit positive sensory responses, leading to increased consumer satisfaction and repeat consumption. In contrast, even nutritionally beneficial products may underperform in the market if the flavor is not well-received. This is particularly relevant in products incorporating less familiar or traditional ingredients such as Masau, which may have strong or unique flavor profiles that require balancing through formulation. A study by Moskowitz et al. (2006) emphasized that tailoring flavor to meet target consumer preferences is essential for achieving strong product uptake and sustainable demand.

Moreover, cultural and regional differences in taste perception significantly influence flavor preference. For example, preferences for sweet, sour, or fermented tastes may vary between urban and rural consumers, or among different age groups and socioeconomic classes (Prescott, 1998). Understanding these demographic and psychographic segments allows producers to develop targeted flavor profiles, increasing the product's relevance in different markets. Failure to consider these factors can result in a mismatch between the product offering and consumer expectations, leading to low trial rates and poor sales performance.

From a marketing and business perspective, flavor preference also affects word-of-mouth promotion, brand perception, and long-term customer loyalty. When consumers enjoy the flavor of a product, they are more likely to recommend it to others, thereby expanding its reach without additional marketing costs. According to Kotler and Keller (2012), customer satisfaction driven by taste can result in a stronger brand-customer relationship and increase the lifetime value of a customer.

Therefore, investing in flavor optimization through sensory evaluation, consumer testing, and iterative product development is vital. These processes help identify ideal flavor intensities, balance, and acceptability levels that appeal to the target market. Technologies such as descriptive sensory analysis and preference mapping are also useful tools for aligning product characteristics with consumer desires (Lawless & Heymann, 2010).

In summary, flavor preference significantly impacts sales volumes by shaping consumer acceptance, influencing repeat purchases, and enhancing market competitiveness. A well-received flavor profile can enhance product success even in saturated markets, while a poorly optimized flavor can undermine the market potential of an otherwise innovative or nutritious product. For producers of beverages like Maheu, especially when experimenting with new ingredients such as Masau, it is crucial to rigorously evaluate and refine flavor formulations to align with consumer expectations.

5.1.3 Effect of Pasteurization Temperature

Pasteurization temperature significantly influenced the product's shelf life, as indicated by pH retention and sensory scores over 21 days. The optimal temperature was 80°C, which minimized pH degradation and maximized sensory attributes by Day 21., supporting the notion that thermal treatment plays a critical role in microbial control and product stability (Steinkraus, 1996). Shelf life is a vital determinant of a food company’s profitability and overall operational efficiency, directly influencing its bottom line. A product with a longer shelf life reduces the likelihood of spoilage and waste, both at the retail and consumer levels. This minimizes financial losses associated with unsold or returned goods and helps maintain profit margins. Perishable products with limited shelf life, such as traditional beverages like Maheu, are particularly vulnerable to spoilage, which can result in significant inventory write-offs. According to Gustavsson et al. (2011), approximately one-third of all food produced globally is wasted, with perishability cited as a major contributor. Extending shelf life through improved formulation, processing, or packaging reduces such losses and contributes to more efficient inventory management.

Furthermore, a longer shelf life enables companies to expand their distribution networks, including into distant or export markets, without the risk of product deterioration during transit. This geographic flexibility enhances market reach and sales potential. Raheem et al. (2019) emphasize that shelf-stable products provide logistical advantages, reducing dependency on costly and rapid distribution systems often required for short-lived products. Additionally, shelf -life extension allows for larger production batches, leading to economies of scale and lower unit costs. It also smoothens supply chain operations by reducing the urgency for frequent restocking and lowering warehousing and transportation costs, as outlined by Nahmias (2011).

Shelf life also plays a critical role in shaping consumer perception and brand loyalty. Products that remain fresh, safe, and palatable throughout their labeled duration reinforce consumer trust and encourage repeat purchases. Spoiled or expired items, on the other hand, can damage brand reputation and lead to long-term revenue loss. Van Boxstael et al. (2014) highlight that consumers often equate shelf life with product quality, influencing both purchasing behavior and customer satisfaction. Additionally, companies must ensure that shelf- life claims meet regulatory standards. Failure to accurately validate and label shelf life can result in legal consequences, including recalls and fines, which further undermine a company’s financial performance and public image.

Shelf life is not merely a technical consideration but a strategic business factor that significantly impacts a company’s financial sustainability. Investing in shelf -life optimization enhances product stability, reduces waste, improves supply chain efficiency, and strengthens market competitiveness. For producers of traditional and functional beverages like Maheu, extending shelf life through appropriate processing and packaging innovations is essential for maintaining profitability and long-term business viability.

5.1.4 Effect of Pasteurization Time

Similarly, pasteurization time affected product stability, with the 15–20 second interval at 80°C being optimal. These durations maintained desirable pH values and sensory quality better than shorter timeframes. demonstrate the strong statistical relevance of pasteurization time in maintaining product integrity, consistent with established food processing standards (Fellows, 2009). Getting the pasteurization time and temperature combination correct is critically important in food and beverage processing, as it directly impacts shelf life, product safety, sensory quality, and ultimately a company's bottom line. Pasteurization is a thermal processing method designed to inactivate pathogenic and spoilage microorganisms, thereby extending the shelf life of perishable products like Maheu. However, the effectiveness of pasteurization hinges on the accuracy of time-temperature control; both under-processing and over-processing can result in significant economic and quality-related consequences.

Undershooting the required pasteurization time may result in incomplete microbial inactivation, leading to premature spoilage, product recalls, and even potential health risks if pathogens survive. This not only shortens shelf life but also exposes the company to legal liabilities, brand damage, and financial losses due to non-compliance with food safety standards (Jay et al., 2005). On the other hand, excessive pasteurization can degrade important nutritional and sensory attributes such as flavor, color, and texture, making the product less appealing to consumers. Heat-sensitive bioactive compounds and volatiles found in ingredients like Masau may be particularly affected, thereby reducing the functional value and market competitiveness of the product (Holdsworth & Simpson, 2007).

Economically, achieving the optimal pasteurization parameters helps maximize processing efficiency and product consistency. Accurate pasteurization minimizes waste due to product rejections and returns, reduces energy and operational costs, and ensures that shelf -life predictions are reliable—an essential factor in supply chain and inventory planning. Companies with poorly defined pasteurization protocols often face increased variability in product shelf life, resulting in inefficient logistics and excess stock losses. Moreover, proper pasteurization enables producers to confidently extend distribution to broader markets, including regions with limited refrigeration infrastructure, thus expanding sales opportunities (Toledo, 2007). From a regulatory perspective, correctly validated pasteurization processes are a core requirement under food safety management systems such as HACCP (Hazard Analysis and Critical Control Points). Inaccurate processing may lead to regulatory sanctions, product seizures, or withdrawal from markets. Hence, investing in scientific validation of pasteurization time, supported by microbial challenge studies and shelf-life testing, is a proactive strategy to safeguard both consumer health and business viability.

In conclusion, precise control of pasteurization time is essential for balancing microbial safety, product quality, and economic efficiency. For beverages like Maheu, which combine natural ingredients with a potential for microbial spoilage, optimized pasteurization ensures a safe, shelf-stable, and sensory-pleasing product. Failure to get this right can lead to significant financial losses, reputational damage, and reduced market competitiveness.

5.2 Summary

This study systematically evaluated the formulation and processing parameters critical to enhancing both the sensory appeal and shelf life of Masau-flavored Maheu. The findings highlight several key factors that contribute to product optimization. A sugar concentration of 10 g per 100 ml was identified as providing the most favorable sweetness profile, balancing palatability without overwhelming the natural flavor of the beverage. Among the two types of Masau flavoring evaluated, Masau juice at a concentration of 100 ml per 100 ml of Maheu was preferred over the paste, due to its superior flavor delivery and consistency in texture. In terms of thermal processing, a pasteurization temperature of 80°C was found to be optimal for preserving pH stability and overall sensory quality over a 21-day storage period. Additionally, a pasteurization time of 15 to 20 seconds at this temperature effectively maintained both the physicochemical integrity and sensory attributes of the beverage. Collectively, these results provide a practical foundation for scaling up the production of value-added Maheu products, ensuring both consumer acceptance and extended shelf life.

5.3 Conclusions

This study effectively demonstrated that the formulation and processing of Masau-flavored Maheu can be systematically optimized to enhance both sensory appeal and shelf life, thereby improving its commercial viability. Through a combination of controlled sensory evaluation and physicochemical analysis, the research identified 10 g of sugar per 100 ml and 100 ml of Masau juice per 100 ml of Maheu as the most preferred formulation, offering a balanced sweetness and favorable flavor profile. Additionally, thermal processing at 80°C for 15–20 seconds was shown to be optimal for maintaining product stability, preserving sensory quality, and extending shelf life over 21 days without compromising nutritional integrity.

The integration of these optimized parameters provides a practical and scalable model for the production of value-added Maheu, especially for small- to medium-scale enterprises seeking to develop shelf-stable, culturally relevant, and consumer-acceptable beverages. The study further highlights the importance of precise pasteurization in ensuring microbial safety and minimizing post-processing losses, which are essential for maintaining profitability and regulatory compliance.

Overall, this research contributes valuable insights into the development of functional traditional beverages using locally available resources, offering opportunities for product innovation, market expansion, and improved food security. Continued research into alternative flavoring agents, sweeteners, and advanced preservation methods will further enhance the product's appeal to diverse consumer segments, including health-conscious and export-oriented markets.

5.4 Recommendations

Based on the findings of this study, several recommendations are proposed to guide future product development and process optimization for Masau-flavored Maheu. In terms of formulation, it is advisable to consider using 10 grams of sugar per 100 milliliters of Maheu and incorporating 100 milliliters of Masau juice per 100 milliliters of base product. This combination demonstrated the most favorable sensory outcomes and may enhance overall consumer acceptance. For thermal processing, pasteurization at 80°C for 15 to 20 seconds is recommended as a potential approach to achieve an optimal balance between shelf- life extension and the preservation of key physicochemical and sensory properties. Further research could explore the inclusion of alternative natural flavorings and sweeteners, particularly low-calorie or plant-based options, to broaden the product's appeal and cater to health-conscious consumers. Additionally, conducting a comprehensive microbial analysis post-pasteurization is recommended to validate the microbiological safety of the product under varying storage conditions, aligning with the findings of Leroy and De Vuyst (2004) on microbial dynamics in fermented foods. These recommendations offer a foundation for scaling up production while ensuring product quality, safety, and market relevance.

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APPENDICES

Appendix 1 : Masau fruit classification

Domain: Eukaryota

Kingdom: Plantae

Phylum: Spermatophyta

Subphylum: Angiospermae

Class: Dicotyledonae

Order: Rhamnales

Family: Rhamnaceae

Genus: *Ziziphus* Mill-Jujube

Species: *Ziziphus mauritiana* (Prakash *et al*, 2021).

Appendix 2: Sweetness Sensory Evaluation Score Sheet

Sample	Sugar Added (g/100ml)	"Not Sweet Enough"	"Good"	"Too Sweet"	Total Respondents
Control (No sugar)	0	11 (Not good)	1	0	12
A1	5	9	2	1	12
A2	10	0	12	0	12
A3	15	0	2	10	12

Notes:

- The "Not Sweet Enough" category includes feedback like "Not good" or "Add more sugar".
- The "Good" category represents ideal sweetness levels.
- The "Too Sweet" category includes respondents who found the sweetness excessive.
- Each column under feedback represents the number of respondents selecting that option.

Appendix 3: Quantitative Sensory Evaluation Score Sheet – Flavor A (Masau Juice)

Sample	Juice Added (ml)	Flavor Intensity (0–4)	Texture (0–3)	Thickness (0–3)	Total Score (out of 10)	Respondents
Control	0	0	0	0	0	12
B1	25	1	1	1	3	12
B2	50	2	3	2	7	12
B3	100	4	3	3	10	12

Interpretation:

- Sample B3 scores the highest in all categories — a total of 10/10, indicating the best overall sensory acceptance.
- Sample B2 shows moderate acceptability.
- Control and B1 score poorly, indicating weak flavor and sensory attributes.

Appendix 4: Quantitative Sensory Evaluation Score Sheet – Flavor B (Masau Paste)

Sample	Paste Added (ml)	Flavor Intensity (0–4)	Texture (0–2)	Thickness (0–3)	Total Score (out of 9)	Respondents
Control	0	1	1	1	3	12
C1	25	1	1	1	3	12
C2	50	2	1	2	5	12
C3	100	4	2	3	9	12

Interpretation:

- While C3 (100 ml paste) scores high on intensity and texture numerically, its thickness and inconsistency in texture made it less preferred.
- Flavor A (juice) was overwhelmingly preferred (10 out of 12), highlighting that strong flavor plus good balance in texture and thickness made it more acceptable.