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Development and Evaluation of Yoghurt Flavoured with Masau (*Ziziphus mauritiana*): Physicochemical, Sensory, and Shelf-Life Analysis

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Abstract

This study explored the development of a yoghurt product flavoured with *masau* (*Ziziphus mauritiana*) and assessed its physicochemical, sensory, and microbiological properties, along with its shelf-life. *Masau* fruits were processed into paste, powder and liquid extract, however the paste was selected as the most suitable flavouring based on sensory attributes evaluation. Raw milk was pasteurized, homogenized, and fermented using a mixed culture of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*, then flavoured with *masau* paste and eventually preserved with potassium sorbate. Two masau flavoured yoghurt variants (sweetened & non-sweetened) were further evaluated for nutrient composition and consumer acceptability using a 9-point Hedonic scale. All masau flavoured yoghurt were preferred overall, especially when sweetened. A *masau* flavoured yoghurt nutritional analysis showed values of 5.46% carbohydrate, 2.01% fat, 3.11% protein, and 51 kcal/100 grams. Shelf-life tests indicated that the preserved yoghurt remained stable for up to 15 days under refrigeration, supporting its potential as a nutritious, locally inspired dairy product.

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Keywords

Masau flavoured yoghurt, pilot plant, fermentation

Introduction

Milk has served as a vital food source for humans for thousands of years, derived from a variety of domesticated and wild mammals. As human societies transitioned from foraging to organized food production, fermentation emerged as a key method for enhancing the longevity and nutritional quality of perishable dairy products (Adam, 1990; Tamime & Deeth, 1980). Among these, yoghurt has gained prominence globally as a highly nutritious, fermented milk product made through the action of specific lactic acid bacteria. Yoghurt plays a significant dietary role in various cultures and continues to be recommended for its health benefits (Buttriss, 2003). Flavoured milk and yoghurt products have gained traction in global markets, particularly for youth and health-conscious consumers (Bisig & Kelly, 2017). These microorganisms particularly *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*—ferment lactose to produce lactic acid, resulting in a thickened, tangy product with diverse textural and sensory properties (Modhu, 2016; Aryana & Olson, 2017). Yoghurt has traditionally been consumed in the Balkans and the Middle East but has since spread worldwide, offering significant nutritional benefits and probiotic functions (Tamime & Deeth, 1980; Behare *et al.,* 2016; Chandan *et al.,* 2017). It is an excellent source of protein, calcium, iodine, phosphorus, potassium, and several essential vitamins, and plays a key role in supporting digestive and immune health (Hadjimbei *et al.,* 2022; Moore *et al.,* 2017; Saviano & Hutkins, 2021).

Ziziphus mauritiana, commonly known as *masau* in Zimbabwe, is indigenous to South Asia and Southern Africa's semi-arid environments, especially in regions like the Zambezi Valley (Arndt *et al.,* 2001; Nyanga, 2012). A member of the Rhamnaceae family, *Z. mauritiana* produces nutrient-dense fruits that can be consumed fresh or dried and are traditionally processed into porridge, non-alcoholic and fermented beverages (Nyanga *et al.,* 2007). The fruit is noted for its dense content of vitamin C, iron, calcium, and carbohydrates, and has been shown to be more nutrient-rich than commercial fruits such as apples and oranges (Rathore, 2009). Despite their abundance and cultural relevance, indigenous fruits like *masau* remain underutilized in Zimbabwe's formal food industry.

This study proposes the development of a novel *masau* yoghurt flavoured product with an intention of bringing a dimension of natural flavour, colour, taste and aroma of masau bioactive compounds. It is interesting to note that, masau-flavoured yoghurt would not only align with global trends toward phytonutrient functional and health-benefiting foods. The yoghurt product flavoured with *masau* (*Ziziphus mauritiana*) was then assessed for its physicochemical, microbiological, sensory characteristics, and shelf-life.

Materials and Methods

Masau Fruit Collection and Preparation

A quantity of 50 kg of sun-dried and ripe *Ziziphus mauritiana* fruits were collected from Bindura Greens Market, Zimbabwe, cleaned, peeled using a dehuller, and the pulp and skin mixture was further dried at 60 °C for 24 hr.

Milk Procurement and Preservation processes

A volume of 50 litres of fresh raw milk was obtained from Henderson Research Station (Mashonaland Central, Zimbabwe). The milk was pasteurised at 90 °C for 15 minutes and then cooled to 40 °C for immediate yoghurt production or to 7 °C for refrigerated storage. Milk directed for non-sweetened yoghurt was added 46.0 g/l of corn starch. On the other hand, milk for sweetened yoghurt was added 10.0 g/l of commercial brown sugar. These additives were introduced at 40 °C through a sieve with continuous stirring to prevent clumping.

Second Pasteurization and Starter Culture Inoculation

After homogenization, the milk mixture was pasteurised again at 90 °C for 15 min and cooled to 42 - 45°C. After then, 5 % (v/v) of commercial Greek-style yoghurt (Kefalos, Zimbabwe, https://www.kefalosfood.com/smooth-yoghurt) inoculum of containing live AB cultures (containing *Lactobacillus bulgaricus* & *Streptococcus thermophilus*) was added, followed by 2–3 minutes of stirring then incubating at 45 °C for 5 - 8 hr. Yoghurt preparations were then kept at ambient temperature for fermentation till pH value of 4.2 - 4.4, then curd was stirred to homogenize, then kept cool at 7 °C.

Yoghurt flavouring with *masau*

Three different types of masau flavouring agents were produced as follows: for *masau* extract a ratio of 1 kg of dried fruits to 4 liters of water was boiled at 90 °C, mashed, and then filtered. For *masau* paste, dehulled and powdered *masau* was mixed with water (1:4), heat to 60 - 70 °C to form a paste. The *masau* powder was generated from pulverized pulp, sieved at 250 micron: and sterilized at 121 °C for 12 min. Each flavouring type was added to 50 ml of plain yoghurt in three concentrations and evaluated for flavour intensity (weak, medium, strong), consistency (runny, medium, thick), texture (bad, neutral, good) and aesthetics (bad, neutral, good). The best flavouring *masau* paste form was then further tested on the flavoured yoghurt to enhance palatability using sugar sweetener. Two yoghurt masau flavoured types were eventually prepared and designated as non-sweetened masau yoghurt and sweetened masau yoghurt at 30 % (w/w) white sugar.

Experimental Design for *masau* flavour modulation on yoghurt

The following table shows the ingredients types and mixture optimization processes considered to prepare the *masau* flavoured yoghurt for fermentation process.

Nutritional Parameter Analysis

All the final yoghurt samples with or with sweeteners were nutritionally profiled for; total carbohydrates, protein, fat, ash content and energy calorific values were determined using ISO-accredited AOAC methods at the Standards Association of Zimbabwe Institute, Zimbabwe. (https://sazportal.saz.org.zw/#/store/categories/6/products).

Sensory Evaluation Experimental Design

A consumer panel of n=35 untrained participants was recruited to evaluate yoghurt samples using a 9-point Hedonic scale. Participants rated each sample based on the following nine attributes on a scale of; 1 (extremely dislike) to 9 (extremely like): general appearance, colour, aroma/smell, palatability, thickness/consistency, taste, sweetness, texture and acidity. Each participant used a scorecard that allowed side-by-side comparison and space for comments. Results were analyzed using one-way ANOVA and Duncan and Tukey HSD multiple comparison procedures to identify which group means are significantly different from each other tests using SPSS v29.0.1.0 (Drake M.A., 2007).

Shelf-Life Testing & Effects of sodium based preservative

About 2 sets of yoghurt samples were prepared as follows: plain (control), *masau* flavoured & sweetened, and *masau* flavoured & non-sweetened), then one set of each were stored at ambient temperature and the other at 4 °C. Each temperature lot had 2 sets comprising of 0.2 % (w/w) sodium sorbate preservative added or without. Aliquots of samples were collected at 2 hr intervals and analyzed for pH, microbial growth, odour, and overall appearance over a 21-day period (Al-Ashmawy *et al.,* 2009).

Microbiological Evaluation

Samples were collected from 1-15 days and then kept under 4 °C and analyzed for total viable count on NA agar, lactic acid bacteria (LAB) on MRS agar and fungal growth on PDA agar. Each yoghurt sample was serially diluted (up to 10^{-8}), plated in duplicate in each specific media type, and incubated (NA and MRS at 37 °C for 48 hours; PDA at 25 °C for 72 hours). Colony counts were expressed as colony-forming units per millilitre (cfu/ml) (American Public Health Association, 2015).

Results and Discussion

Sensory Evaluation of *masau* paste and extract as yoghurt flavourants

The sensory evaluation of the two (2) yoghurt *masau* flavoured types; *masau* extract and *masau* paste in comparison to the plain yoghurt, revealed distinct differences in their sensory attributes (Table 2). Plain yoghurt, serving as the control, was consistently rated as having a medium consistency, which was considered ideal, but it lacked flavour intensity and was rated neutral for texture and aesthetics, reflecting its unflavored nature.

masau extract was generally perceived as having weak flavour intensity across all concentrations, with some respondents noting a slight increase at the highest concentration. However, its consistency was problematic, shifting from medium at low concentration to runny and thin at higher levels, which detracted from its appeal. Elsewhere, findings showed that additives or extracts can thin out the yoghurt product (especially affecting consistency and texture) depending on concentration and interaction with the fermentation culture conditions (Beal *et al.,* 1999). Similar work with mango pulp fruit pulps improved flavour and appearance only at moderate concentrations, while over-fortification led to undesirable consistency (Yogesh *et al.,* 2013; Hassan *et al.,* 2016). Flavour generation in dairy products often relies on both microbial metabolism and added fruit compounds (Boelrijk *et al.,* 2003).

Texture ratings remained mostly neutral, with only occasional positive feedback at the highest concentration, and aesthetics were largely neutral, with no notable improvement in appearance. This result is supported from other researchers who showed that plant-based additives or bases can affect flavour perception and texture neutrality in yoghurt, aligning with the weaker flavour and neutral texture ratings observed in *masau* extract samples. Mirror findings where recorded when apple pulp was used affecting flavour and consistency ideally the same (Minhas *et al.,* 2017).

In contrast, *masau* paste (MP) showed a clear dose-dependent increase in the flavour intensity, ranging from weak to strong, which was well-received by the panelists in comparison to the *masau* extract. The consistency of the yoghurt however, remained medium across all concentrations, aligning well with an ideal yoghurt texture. Texture quality was positively rated as good for at the highest concentration, and aesthetics received consistently good ratings throughout the mixtures indicating a visually appealing product. Overall, *masau* paste against *masau* extract was noted to be the most favored flavouring agent, offering the best balance of the majority of the attributes: flavour, texture, and appearance. In turn, making it the optimal form choice for enhancing yoghurt palatability and consumer acceptance. Hence, *masau paste* was the most suitable form for yoghurt flavouring under the analyzed parameters.

A further interrogation of the possibilities of flavouring differences was performed using the one way ANOVA analysis. (Table 3. It was similarly noted that, the general appearance of the differently flavoured yoghurt had significant differences among the three samples ($p < 0.05$), meaning panelists rated them differently in how they looked. Interestingly, attributes of aroma, taste, texture, palatability: showed no statistically significant differences whereby, $p > 0.05$, suggesting the panelists found them to be quite similar across samples in these categories. Such results have been recorded whereby plant based extracts affect.

However, a more concise analysis to elucidate on the individual and group differences a further Tukey HSD post hoc analysis was performed. The Tukey HSD post hoc analysis for general appearance provides a deeper understanding of the differences in perceived visual appeal among the three yoghurt types: control/plain, *masau* paste-flavoured, and *masau* powder-flavoured. The results reveal that the control sample was rated significantly higher in general appearance compared to both the *masau* paste-flavoured and *masau* extract-flavoured yoghurt. Specifically, the control sample had a mean score that was 1.06 points higher than *masau* extract-flavoured and 1.17 points higher than *masau* paste-flavoured on the 9-point Hedonic scale. These differences were statistically significant ($p < 0.01$), indicating that participants consistently preferred the appearance of the control yoghurt. In contrast, there was no significant difference between the *masau* paste and extract flavoured yoghurt themselves (*masau* extract vs *masau* paste, $p = 0.85$), suggesting that the type of *masau*-based flavouring did not markedly impact the visual appeal of the product.

Overall, these findings suggest that while traditional yoghurt (control) had a more favorable appearance, both *masau*-enriched versions were similarly perceived, potentially indicating a need for aesthetic improvement in both formulations to match consumer expectations.

Such similar results using plant-based enrichment impacts flavour and mouthfeel, similar to *masau* extract (Olakunle *et al.,* 2020). Interestingly, there was a noted significant difference between the control/plain and both *masau* extract and *masau* paste flavoured in terms of general appearance ($p < 0.05$) (Table 4). However, there was no significant difference found between *masau* extract and *masau* paste ($p = 0.85$). In conclusion, plain yoghurt served as the control and had consistent but neutral scores across most attributes. On the other hand, *masau* extract-flavoured yoghurt was less effective due to weak flavour perception and undesirable consistency (runny or gritty). However, *masau* paste-flavoured yoghurt outperformed others in flavour intensity, texture, and appearance, with a clear dose-response trend, making it the best option for product development as noted elsewhere when using natural plant extracts and pulps (Wong & Camirand, 2003; Obi *et al.,* 2007; Olakunle *et al.,* 2020).

Storage Temperature Effects on Modulating Masau-Flavoured Yoghurt

The storage temperature played a critical role in modulating the pH stability and perceived sweetness of masau-flavoured yoghurt over time. As illustrated in Figure 2, the pH profiles of both powder-flavoured (**A**) and paste-flavoured (**B**) yoghurt was monitored under ambient storage (~25 °C) with the inclusion of a preservative. Three treatments were compared: control, sweetened masau extract/paste, and unsweetened masau extract/paste.

Yoghurt Stored at 4 °C (Cold Storage)

Though not directly shown in the figure, yoghurt samples stored at 4 °C (refrigeration) in parallel trials exhibited a slower decline in pH, from pH 4.4 to 3.8. This slower acidification reflects reduced fermentation activity due to suppressed lactic acid bacteria metabolism. Under these conditions, both control and masau-enriched formulations retained higher pH values throughout storage, indicating greater stability and delayed sourness development.

Notably, the sweetened extract maintained sensory sweetness longer, likely due to reduced sugar breakdown and possible buffering effects. Refrigeration thus modulates yoghurt by: minimizing metabolic acidification (Dave & Shah, 1997, Beal *et al.,* 1999; Lourens-Hattingh & Viljoen, 2001, Adolfsson *et al.,* 2004) preserving sugar content, enhancing sweetness perception and prolonging shelf-life and maintaining sensory appeal (Lourens-Hattingh & Viljoen, 2001; Shiby & Mishra, 2013). To complement efforts of shelf-life, the use of preservatives such as potassium sorbate and sodium sorbate has been studied to extend shelf life in dairy analogues like soya-based yogurt.

Yoghurt Stored at ~25 °C (Ambient Storage)

Figure 2A and 2B illustrates the pH changes in masau-flavoured yoghurt stored at 4 °C with a preservative over time. In both powder-flavoured (A) and paste-flavoured (B) yoghurts, pH generally decreased gradually, indicating ongoing acidification due to microbial activity (for A it changed from 4.4 to 3.9 and in 3B from 4.4 to 3.9). The control samples showed a more stable pH, while sweetened masau treatments exhibited a slightly faster decline, likely due to sugar-enhanced fermentation. Unsweetened masau treatments also showed acidification but at a moderate rate, suggesting that both the form of masau and sugar content influence pH stability during refrigerated storage.

As observed in Figure 3A and 3B, ambient temperature storage (~25 °C) led to a faster pH decline, reaching as low as 3.6 in some treatments. This is indicative of accelerated fermentation, particularly in the unsweetened masau extract/paste samples (■), which exhibited the steepest drop in pH. The absence of added sugars as recorded by other researchers, likely intensified acid production due to the lack of fermentable carbohydrates or buffering agents (Tamime & Robinson, 2007). Conversely, the sweetened formulations showed slightly more pH stability, possibly due to residual sugars moderating fermentation rate and offering some taste masking. However, even in sweetened samples, sensory sweetness decreased over time as acidity increased, especially in the second half of storage.

Ambient temperature thus modulates yoghurt by; accelerating lactic acid production, shortening sensory acceptability window and intensifying sourness, particularly in unsweetened variants as noted elsewhere (Vasiljevic & Shah, 2008)

Nutritional Parameter Analysis

The nutritional analysis of the masau-flavoured yoghurt revealed a balanced composition suitable for a possible functional dairy product (see Table 5). It was observed that per 100 g serving, the flavoured yoghurt provided 3.11 % protein, which is a moderate level supportive of dietary protein intake, especially in fermented dairy (cite reference). The fat content was relatively low at 2.01 %, making it appropriate for health-conscious consumers, while the carbohydrate level at 5.46 %, was likely to be influenced by both milk sugars and residual fruit sugars from masau. The product delivered 51 kcal (213 kJ) of energy, reflecting its light, nutrient-dense profile. Additionally, the ash content of 0.88% indicates the presence of natural essential minerals. Overall, the yoghurt demonstrated a nutrient profile consistent with functional foods, offering protein, energy, and trace minerals while remaining low in fat, thereby making it a suitable candidate for health-promoting dietary applications.

Microbial Counts in *masau* flavoured Yoghurt

Understanding the microbiology of yoghurt is crucial in ensuring product safety and consistency (Bryan, 2021). After having realized that the *masau* paste flavoured was the most preferred *masau* flavoured yoghurt, we zeroed on it for microbial development during storage over a period of a week. On day 1, all samples showed high total bacterial counts (TBC), with the paste non-sweetened sample having the highest TBC (12.5×10^9 cfu/ml) and LAB (7.0×10^9 cfu/ml), while fungi and molds were absent in the control and lowest in the paste non-sweetened. By day 7, microbial loads increased across all samples. The paste sweetened sample had the highest TBC (18.5×10^9 cfu/ml), LAB (8.5×10^9 cfu/ml), and fungi/mold counts (5.0×10^9 cfu/ml). In general, sweetened paste showed the most microbial activity over time, indicating accelerated fermentation, while the control remained lowest in fungi/molds throughout.

Discussion

The evaluation of masau extract and masau paste as yoghurt flavourants demonstrated key differences in sensory, microbial, and physicochemical properties, which collectively informed the most suitable formulation for product development. From a sensory standpoint, masau paste-flavoured yoghurt displayed superior performance compared to both the plain control and masau extract samples. A clear dose-dependent increase in flavour intensity was observed with paste inclusion, alongside ideal medium consistency, improved texture, and consistently high aesthetic appeal. These findings align with previous work showing that fruit pulps such as mango and apple can enhance yoghurt sensory quality when applied at optimal concentrations (Minhas *et al.,* 2017; Hassan *et al.,* 2016).

Figure.1 Production processing stages in the development of yoghurt fortified with indigenous masau fruit paste and extract.

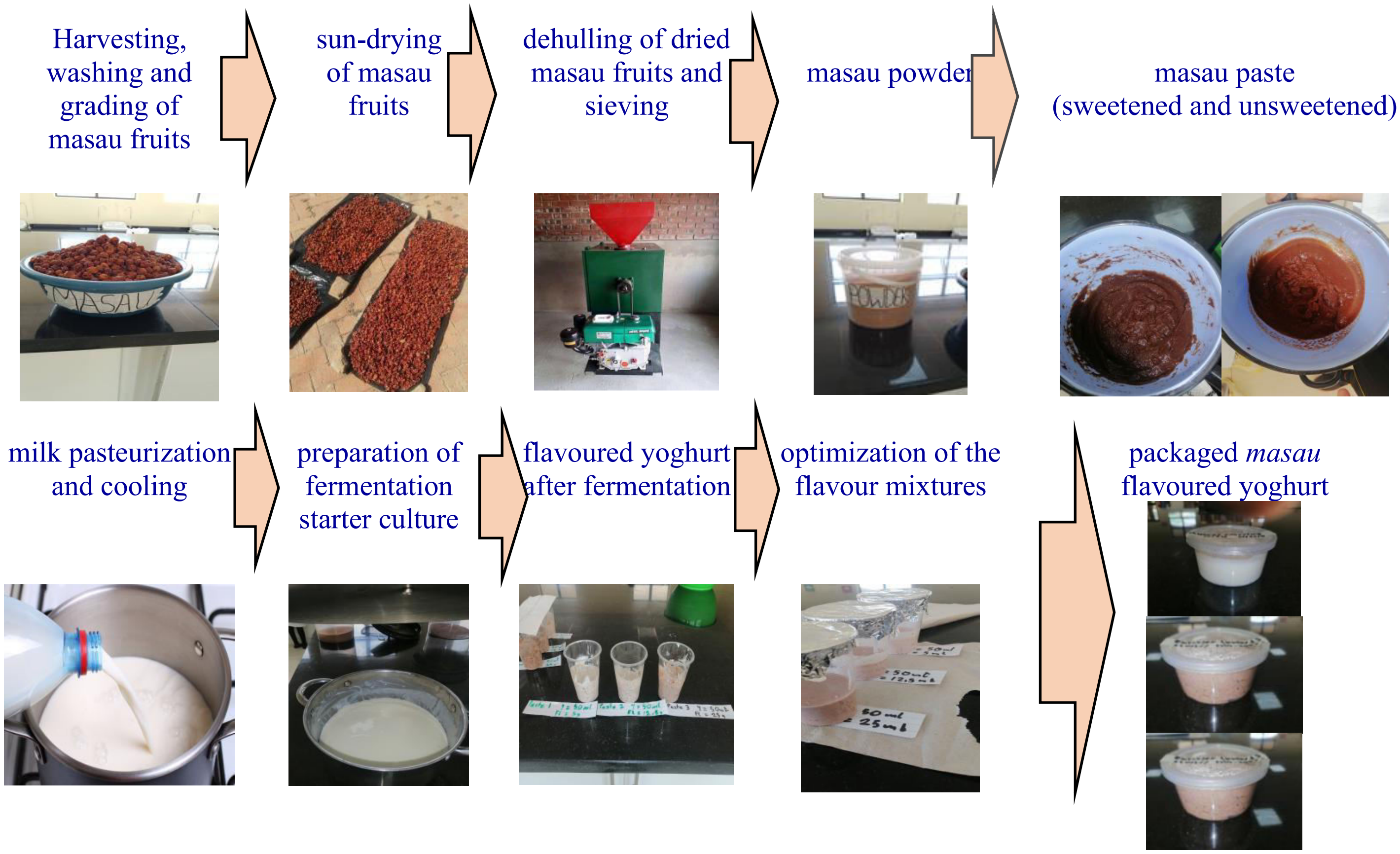


Figure.1 Box-plot analysis illustrating the sensory evaluation scores for the three yoghurt types *masau* paste, *masau* powder, and reference/control, across five sensory attributes.

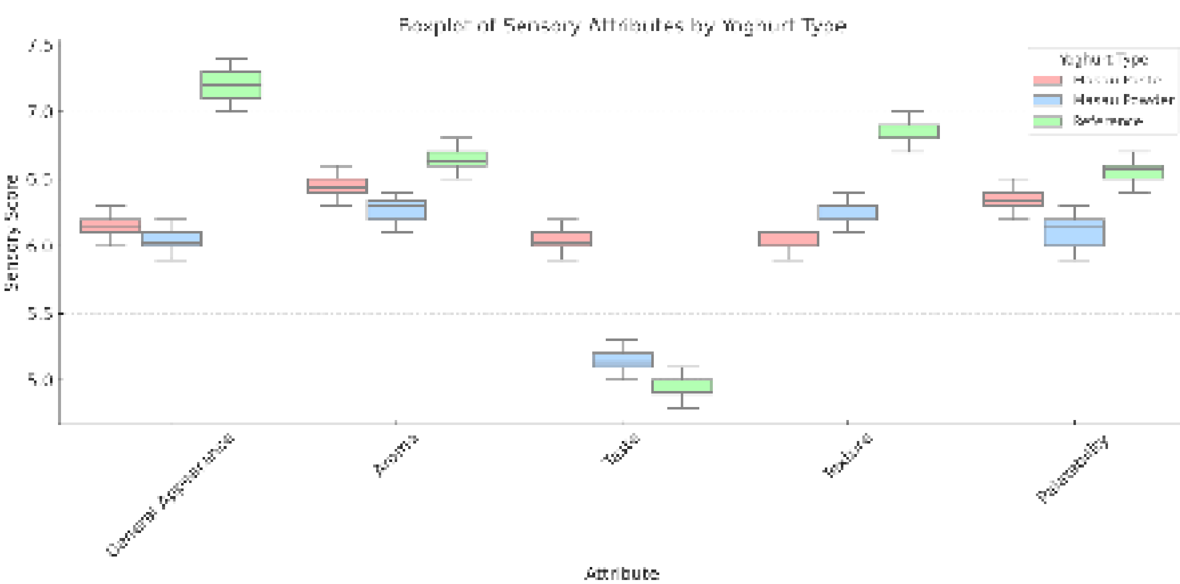
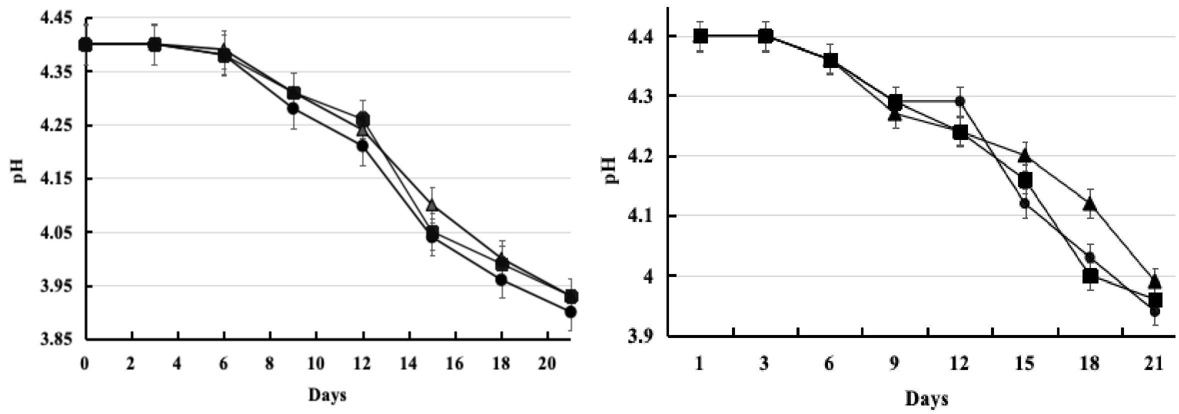
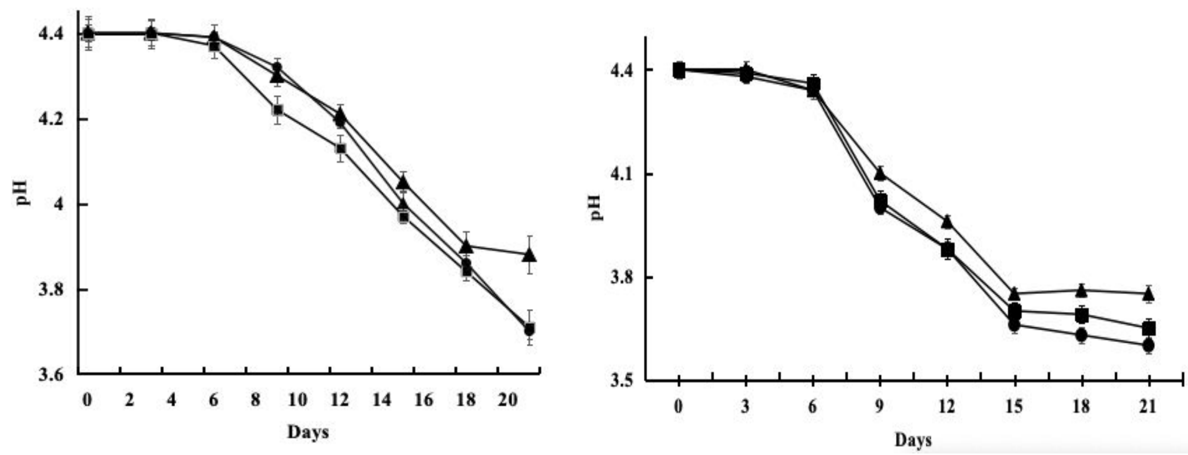


Figure.2 Changes in pH of *masau*-flavoured yoghurt stored at 4 °C temperature with preservative. (A) powder-flavoured yoghurt and (B) paste-flavoured yoghurt. treatments include: control (▲), sweetened *masau* (●), and unsweetened *masau* (■).



A *masau* powder flavoured **B *masau* paste flavoured**

Figure.3 Changes in pH of *masau*-flavoured yoghurt stored at ambient temperature (~25 °C) with preservative. (A) powder-flavoured yoghurt and (B) paste-flavoured yoghurt. treatments include: control (▲), sweetened *masau* (●), and unsweetened *masau* (■).



A *masau* powder flavoured **B *masau* paste flavoured**

Table.1 Summary of the mixtures of the masau yoghurt combinations

Yoghurt Type	Flavouring Form	Key Ingredients	Sweetening	Preservative
plain yoghurt (Reference)	None	milk + starter culture	No	No
***masau* paste-flavoured**	*masau* paste	milk + starter culture + *masau* paste (from powder + water) + sugar (optional)	Yes / No	Yes / No
***masau* pwder-flavoured**	*masau* powder	milk + starter culture + fine *masau* powder	Yes / No	Yes / No

Table.2 Summary of Sensory Evaluation of the plain, *masau* powdered, and *masau* paste-flavoured yoghurt.

Attribute	plain/control yoghurt	*masau* powder-flavoured yoghurt	*masau* paste-flavoured yoghurt
Flavour Intensity	Not applicable (no flavouring added)	Weak to medium at best (depending on concentration)	Clear dose-dependent increase: weak → medium → strong
Consistency	Consistently medium across all respondents	Often runny or thin at higher doses	Uniformly rated as medium – ideal yoghurt texture
Texture	Neutral - no special mouthfeel	Neutral to slightly gritty at higher dose	Improved texture with higher paste concentration
Aesthetic Appeal	Neutral - plain appearance	Bland or neutral; sometimes described as cloudy	Consistently rated good - better visual appeal

Table.3 Results of the one-way ANOVA analysis for each sensory attribute comparing *masau* extract, *masau* paste flavoured yoghurt, and the plain (control).

Attribute	F-statistic	p-value
General appearance	4.64	0.012 ★
Aroma	0.29	0.749
Taste	2.52	0.086
Texture	1.82	0.168
Palatability	0.44	0.647

Table.4 Multiple Comparison of Means - Tukey HSD, FWER=0.05.

Group 1	Group 2	mean diff.	p-adj	lower	upper	reject
plain/control	*masau* extract	-1.06	0.001	-1.67	-0.45	True
plain/control	*masau* paste	-1.17	0.001	-1.78	-0.56	True
***masau* extract**	*masau* Paste	-0.11	0.8531	-0.72	0.50	False

Table.5 Main macronutrient and energy composition of *masau*-based functional yoghurt

Nutrition information	Content/100 g
Ash	0.88 %
Carbohydrates	5.46 %
Energy	51 kCal
Fat	2.01 %
Protein	3.11 %
Density	52.65 g

Table.6 Microbial evaluation over 7 days period of the paste favoured *masau* flavoured yoghurt

Sample	day	TBC (cfu/ml)	LAB (cfu/ml)	Total fungi & molds (cfu/ml)
control	1	$9 \pm 2.83 \times 10^9$	$4.5 \pm 0.71 \times 10^9$	0
paste sweetened	1	$11.5 \pm 3.54 \times 10^9$	$6.5 \pm 1.58 \times 10^9$	$2. \pm 0.41 \times 10^9$
paste non-sweetened	1	$12.5 \pm 0.71 \times 10^9$	7.0×10^9	$5.0 \pm 0.71 \times 10^8$
control	7	$13 \pm 2.83 \text{ x } 10^9$	5.0×10^9	$2.5 \pm 0.71 \times 10^9$
paste sweetened	7	$18.5 \pm 0.71 \times 10^9$	$8.5 \pm 0.71 \times 10^9$	$5.0 \pm 1.41 \times 10^9$
paste non-sweetened	7	$13.5 \pm 3.54 \times 10^9$	$7.5 \pm 2.12 \times 10^9$	$4.0 \pm 0.41 \times 10^9$

Conversely, masau extract was associated with weak flavour and undesirable runny consistency at higher concentrations, a phenomenon explained by the dilution of yoghurt matrix and disruption of fermentation structure by water-based extracts (Beal *et al.,* 1999).

Statistical analysis (ANOVA) revealed a significant difference in general appearance ($p = 0.012$) among the samples, while other attributes such as aroma, taste, and palatability showed no significant differences. Tukey HSD post hoc tests confirmed that the control was significantly preferred in appearance over both masau-flavoured yoghurts, though there was no difference between masau paste and extract themselves ($p = 0.85$). This suggests that while plant-based additives may compromise visual appeal (possibly due to cloudiness or sedimentation), they can still preserve core sensory attributes (Olakunle *et al.,* 2020).

Microbial analysis further reinforced the functional potential of masau-flavoured yoghurt. Total bacterial counts (TBC) and lactic acid bacteria (LAB) populations increased over the 7-day period, with sweetened paste yoghurt showing the highest microbial load by Day 7 (TBC: 18.5×10^9 cfu/ml; LAB: 8.5×10^9 cfu/ml), followed by paste non-sweetened and control. The growth of LAB is beneficial as it enhances probiotic content, improves product digestibility, and contributes to lactic acid production, which helps in natural preservation (Dave & Shah, 1997; Lourens-Hattingh & Viljoen, 2001). However, fungi and molds also emerged over time, particularly in non-refrigerated samples, with higher counts observed in paste sweetened yoghurt. Yeast species in traditional yoghurts have been identified and shown to impact microbial stability (Ayşe *et al.,* 2019).

This highlights the need for strict cold storage protocols, especially when natural fruit pulps are introduced, as their sugar and moisture content can promote spoilage microorganisms.

Storage temperature played a critical role in modulating microbial dynamics and pH trends. At 4 °C, yoghurt samples—including masau-flavoured variants—maintained a gradual pH decline (4.4 to ~3.9), indicating slower fermentation and reduced LAB metabolism. This prolonged the product's sensory and microbiological stability, with sweetened samples retaining better sweetness perception due to slower sugar degradation and a mild buffering effect (Beal *et al.,* 1999; Shiby & Mishra, 2013). In contrast, ambient storage (~25 °C) resulted in a more rapid pH drop (as low as 3.6), especially in unsweetened samples, driven by accelerated lactic acid production in the absence of sugar buffers. This environment favored faster microbial growth and sourness development, shortening the product's acceptability window (Tamime & Robinson, 2007).

Nutritionally, masau paste-enriched yoghurt offered a desirable macronutrient profile, delivering 3.11% protein, 5.46% carbohydrates, and 2.01% fat per 100 g. The energy yield of 51 kcal/100 g reflects a light yet nutrient-rich dairy food, appropriate for functional and health-conscious markets. The ash content (0.88%) indicates the presence of trace minerals derived from the masau fruit, contributing to the product's overall micronutrient density.

In conclusion, masau paste significantly outperformed masau extract in enhancing yoghurt's sensory and textural qualities, while also supporting beneficial microbial growth. Refrigeration was essential in preserving both microbial quality and sensory appeal, and sweetened variants showed better microbial and physicochemical stability. Together, these findings support the inclusion of masau paste as a promising natural flavourant and functional additive in yoghurt, aligning with trends in indigenous fruit valorization, nutrition security, and agro-processing innovation.

This study demonstrates the superiority of masau paste over masau extract as a natural yoghurt flavourant, based on integrated sensory, microbial, physicochemical, and nutritional analyses. Sensory evaluation showed that masau paste significantly enhanced flavour intensity, texture, and appearance, with a consistent dose-response trend, while masau extract weakened yoghurt consistency and delivered only weak flavour findings that mirror prior reports on the impact of fruit pulps versus extracts in fermented dairy (Hassan *et al.,* 2016). Microbiologically, *masau* paste supported higher lactic acid bacteria (LAB) counts and total viable populations over storage, contributing positively to fermentation and potential probiotic activity (Dave & Shah, 1997). However, fungal growth was more prominent in sweetened samples, underscoring the importance of cold storage. Physicochemically, refrigerated samples maintained more stable pH values and sensory sweetness over time, while ambient storage accelerated acidification and sourness, particularly in unsweetened variants. Nutritionally, masau-flavoured yoghurt provided a balanced macronutrient profile-rich in protein and carbohydrates with low fat—suitable for health-conscious consumers and functional food markets. Collectively, these findings support the valorization of indigenous fruits like masau in fermented dairy systems, with masau paste offering a practical, sensory-appealing, and nutritionally relevant option for yoghurt enhancement. Similar acceptability trends have been observed in baobab-fortified yoghurts in Zimbabwe, which showed good consumer ratings (Chipurura *et al.,* 2014). Finally, the current findings align with earlier work documenting the diverse health benefits of various yoghurt types (Banerjee *et al.,* 2017).

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