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RESEARCH PAPER

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Optimization of maltodextrin as a bulking agent in mango (*Mangifera indica*) fruit bar: Physical, sensory, and nutritional evaluation

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ABSTRACT

This study aimed to determine the optimum level of maltodextrin incorporation as a bulking agent in the production of mango fruit bars and to evaluate their physical properties, sensory acceptability, proximate composition, and vitamin C content. Mangoes were processed through washing, peeling, deseeding, depulping, and pureeing, followed by the incorporation of maltodextrin at 1%, 3%, and 5% (w/w), with a control formulation containing no maltodextrin. The mixtures were adjusted to 25°Brix total soluble solids (TSS), heated, sulfited, dried at 55°C for 17 hours, molded, and packaged. The physical properties of the fruit bars were evaluated by measuring thickness, while sensory acceptability was determined using a 9-point Hedonic Scale with 25 panelists. The optimum formulation was further analyzed for proximate composition and vitamin C content and compared with the control. Results showed that increasing the maltodextrin concentration significantly increased the thickness of the mango fruit bars, with the 3% and 5% formulations producing thicknesses of 9.38 mm and 10.63 mm, respectively. Sensory evaluation revealed that the formulation containing 3% maltodextrin obtained the highest acceptability scores, particularly for texture, flavor, and overall acceptability. Proximate composition analysis further demonstrated that the 3% maltodextrin formulation contained significantly higher ash (1.455%), protein (2.495%), total dietary fiber (3.775%), and vitamin C (40.350 mg/100 g) than the control ($p < 0.05$), while moisture and carbohydrate contents were comparable between formulations. Although the control exhibited a slightly higher fat content, both formulations remained low in fat. These findings indicate that the incorporation of 3% maltodextrin improved nutrient retention and enhanced the nutritional quality of the mango fruit bars without compromising their desirable physical characteristics. In conclusion, the incorporation of 3% maltodextrin was identified as the optimum formulation for producing mango fruit bars with desirable physical properties, high sensory acceptability, and improved nutritional quality.

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INTRODUCTION

Fruits hold significant economic value in the marketplace. The Food and Agriculture Organization of the United Nations (FAO) reports that in 2021, pineapple, avocado, and mango were the three most traded tropical fruits based on export volumes, with mango accounting for 29% of exports, totalling 2.3 million tons (including mango, mangosteen, and guava) and showing an average growth rate of 1.9% compared to the previous year (Canton, 2021). Mango is particularly popular and economically significant in tropical regions across Asia, South America, Hawaii, Central America, the Caribbean, and Africa, with India as the leading producer, supplying about 50% of the world's mangoes, despite being a seasonal fruit (Zahedi *et al.*, 2016). India is the world's leading mango producer, with China, Thailand, Pakistan, Mexico, and Indonesia also among the major mango-producing countries (Bhosale et al., 2016).

The Philippines plays a significant role in the global mango value chain, particularly in processed mango products. In 2014, the country's processed mango exports were valued at approximately US$91 million, with dried mangoes accounting for the largest share (77%), followed by mango juice (9%), airtight mango products (8%), and mango puree (7%) (Ahmed *et al.*, 2017). Mangoes (*Mangifera indica* L.) are vital for industry growth and symbolize Filipino identity as the national fruit. Celebrated as one of the Philippines' most significant crops, mango is known as the "king of fruits" for its exceptional flavor, enticing aroma, vibrant colors, delicious taste, and high nutritional value (Hui, 2006). The Department of Agriculture (DA) reports a growing demand for mango products, driven by rising incomes, a preference for healthy foods, and reduced trade barriers in the global market. Key export markets for mangoes include France, the Netherlands, the United Kingdom, the United States, and Spain (Domingo *et al.*, 2017).

Despite this potential, the FAO estimates that one-third of globally produced food is lost or wasted, representing a significant loss of resources needed for production, processing, and distribution, and posing a threat to food security (FAO, 2011). In 2016, around 13.8% of food produced worldwide was lost before reaching retail, with nearly 21% of that loss attributed to fruits and vegetables (FAO, 2019). The perishable nature of fruits contributes to postharvest losses, resulting in economic harm for producers, distributors, and the agricultural sector overall. This spoilage is aggravated by microbiological degradation, transportation issues, marketing challenges, and inadequate handling conditions (Singh *et al.*, 2022). In the Philippines, agriculture accounts for about 8.6% of GDP, but the high-volume, low-value, and highly perishable nature of products leads to significant food waste during distribution. Factors such as the tropical climate, inadequate post-harvest infrastructure, and complex distribution systems can result in post-harvest losses of up to 50% from harvesting to consumer delivery (Mopera, 2016).

To address this issue, processing and preservation offer practical approaches for reducing postharvest losses and extending the shelf life of perishable fruits. Appropriate processing methods can maintain product quality, improve availability, and add value to harvested produce (Barbosa-Cánovas *et al.*, 2003). Thus, it is essential to explore alternative methods to reduce fruit losses or waste. One effective approach is converting fruit pulps into fruit bars or fruit leather. A fruit bar is a dehydrated, shelf-stable product that serves as a confectionery item (Tiwari, 2019). Dehydration significantly extends the shelf life of fruit, helping to minimize product waste and economic losses (Nguyen *et al.*, 2022).

Fruit bars are often marketed as natural snacks in the health food sector and are perceived by consumers as healthier options (Ruiz *et al.*, 2012). They provide a nutritious alternative to high-fat or high-sugar sweets, cookies, and cakes, being convenient for packaging and transport. Processing fruits into fruit bars or fruit leather is beneficial, as it allows the use of fully ripe fruits, which have higher sugar content, better flavor, and carotenoid levels, as well as culled or overripe fruits. Mechanizing the pulping process reduces labor intensity and enables full utilization of the pulp and added ingredients, resulting in minimal waste and processing losses compared to other methods (Tiwari, 2019). Fruit bars are recognized for their high nutritional and energy content, being dehydrated and concentrated products with a long shelf life. Their wholesome nutrition and great taste make them appealing to a wide audience. Convenient to carry, fruit bars serve as portable food, providing essential dietary fiber, vitamins, minerals, and other bioactive compounds that support human nutrition (Ruiz *et al.*, 2012).

In the Philippines, the Carabao mango, also known as Manila super mango, is regarded as one of the best and sweetest mangoes globally, alongside other popular varieties such as Pico, Katchamita (Indian), and Pahutan (FAOSTAT, 2018). The pulp of mangoes, primarily made up of carbohydrates and acid, is the most commonly consumed part. Processed products include juices, concentrates, jams, fruit bars, chutneys, and dried fruit (Schieber *et al.*, 2000), with Carabao mango being widely used for making fruit bars and leather (Azeredo *et al.*, 2006). The conventional steps for making fruit bars begin with converting fruit into pulp or using fruit pulp or puree, followed by mixing ingredients, heating for concentration, spreading on trays, and drying using suitable systems. Different drying methods can be employed, including electrical dryers, convective dryers, convective-solar dryers, microwaves, and vacuum dryers (Ruiz *et al.*, 2012). There are also innovative possibilities such as developing gelled fruit matrices or extruded forms, which represent new trends in processing products similar to fruit bars. To make fruit bars, various types of sugars (sucrose, maltodextrin, glucose, juice concentrates), pectin as a binder, and other additives (e.g., acids, preservatives, colors, and flavors) are necessary (Orrego *et al.*, 2014). At present, there is no standardized formulation for producing fruit bars that achieves the desirable chewy consistency preferred by consumers while also ensuring a prolonged shelf life (Sukasih *et al.*, 2022). Thus, this study aimed to develop new formulations of fruit bars from mango added with maltodextrin as thickening agent or thickening agent and to assess the physical and sensorial properties of the fruit bars.

MATERIALS AND METHODS

Raw materials and preparation of fruit puree

Fresh, fully-ripened but firm Carabao mangoes were obtained from the mango plantation of the Cagayan State University-Piat Campus. The mangoes were brought to the CSU-DTI 2 Shared Service Facility (SSF) for Tropical Fruits Processing of the campus where the study was conducted. Damaged fruits were discarded. Mangoes were washed thoroughly, peeled, and pulps were separated from the seed manually with a stainless steel knife. Using an electric fruit pulper, mango pulps were pureed. Mango puree were placed in clean stainless steel containers with cover then placed in a freezer until further use. Food additives and preservatives such as maltodextrin, citric acid, and sodium metabisulfite, and small PET jars with cover as packaging materials were purchased in the market.

Preparation of mango fruit bars

One kilogram (1 kg) of mango puree was placed in a stainless steel container. Maltodextrin was added to the puree at concentrations of 1% (w/w), 3% (w/w), and 5% (w/w) (Table 1). For the control, there was no maltodextrin added. Citric acid was added at a rate 0.15% (w/w) to adjust the pH of the mixture. The initial total soluble solids (TSS) of the fruit puree mixture was determined using a hand refractometer. White refined sugar was added into the mixture to adjust the TSS until 25°Brix was achieved. The fruit puree mixture was blended using a food processor. The mixture was then heated to 80°C for 2 minutes and left to cool to 40°C for about 30 minutes. Sodium metabisulfite, an anti-browning agent, was added to the mixture at 0.15% (w/w) concentration, then mixed thoroughly. Each batch of formulation was poured and spread into a stainless steel tray lined with plastic sheet. The tray from each formulation was loaded in a cabinet drier then dried at 55°C for a total of 17 hours. After drying, the tray was unloaded then the cool and dried mango fruit leather was removed and placed on a clean stainless steel table partially dusted with powdered sugar. The mango fruit leather was cut into 3 sheets then stacked into 3 layers. The stacked mango fruit leathers were evenly cut into small squares, about 1"x 1", forming into mango fruit bars. Fruit bars were dusted with powdered sugar. Coated mango fruit bars were then packed into PET jars then covered using an induction sealer. Packed mango fruit bars were placed in a cool, dry place.

Table 1. Formulations of mango fruit bar added with 1%, 3%, and 5% (w/w) maltodextrin

Mango fruit bar formulation	Mango puree (g)	Maltodextrin(g)	Citric acid (g)	Sugar (g)	Sodium metabisulfite (g)
A (Control)	1000	0	1.5	90	1.5
B	1000	10	1.5	87	1.5
C	1000	30	1.5	84	1.5
D	1000	50	1.5	80	1.5

The method of preparation used in this study was adopted from the methods used by Domingo *et al.* (2017), but with some modifications. Fig. 1 shows overall preparation process of mango fruit bar conducted in this study.

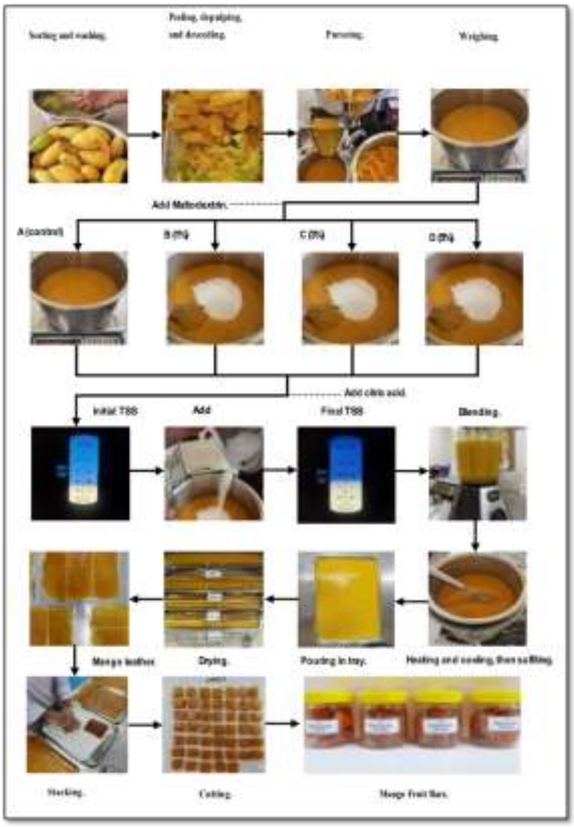

Fig. 1. A diagram showing the preparation of mango fruit bars added with 1%, 3%, and 5% (w/w) maltodextrin

Sensory evaluation

Fruit bar samples were rated according to preference, based on the 9-point Hedonic scale with 25 panelists which consisted students, faculty, and staff of Cagayan State University-Piat Campus, on the following sensory attributes: color, aroma, flavour, texture (chewiness) and general acceptability. Mango fruit bars must meet the following criteria: The mango fruit bars should exhibit a firm texture while maintaining a soft and flexible consistency, a dark yellow to orange brown, a distinctive mango aroma, moderate sweetness, and balanced acidity in the product (Ahmad *et al.*, 2005). The scale ranges from 1 to 9. In which, 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely (Sharif *et al.*, 2017). The samples were placed in plastic canisters labeled with a random three-digit code and were randomly presented. Water was provided for rinsing between samples.

Statistical analysis

The data obtained from sensory evaluation were subjected to Analysis of Variance (ANOVA) at 5% level of significance, to determine whether or not there is a significant difference between the treatments. Duncan's New Multiple Range Test (DNMRT) was further employed to determine which treatments were significantly different from each other. The most preferred formulations were determined.

Proximate composition and vitamin C analysis

The optimum mango fruit bar formulation containing 3% maltodextrin, which was selected based on its highest sensory acceptability scores obtained during the sensory evaluation, was subjected to proximate composition and vitamin C analyses together with the control formulation without maltodextrin. The analyses were conducted at an accredited analytical laboratory.

The proximate composition, including moisture, ash, crude protein, crude fat, total dietary fiber, and carbohydrate contents, was determined using the Official Methods of Analysis of AOAC International (21st Edition, 2019). Moisture content was determined by the oven-drying method, ash content by dry ashing, crude protein by the Kjeldahl method, crude fat by solvent extraction, and total dietary fiber by the enzymatic-gravimetric method. Carbohydrate content was calculated by difference.

Vitamin C (ascorbic acid) content was determined using High-Performance Liquid Chromatography (HPLC) following the standard analytical procedure of the testing laboratory. The results were expressed as milligrams of vitamin C per 100 grams (mg/100 g) of sample.

Statistical analysis

The analytical results were expressed as mean ± standard deviation. Differences between the optimum mango fruit bar formulation containing 3% maltodextrin and the control formulation without maltodextrin were analyzed using an independent samples t-test at a 5% level of significance ($p < 0.05$).

RESULTS AND DISCUSSION

Physical characteristics of mango fruit bars

The fruit composition plays a crucial role in the quality of fruit bar or leather, as the added ingredients in the formulation can affect both the nutritional and structural properties of the final product (Ciurzyńska *et al.*, 2019). Fig. 2 shows the final appearances of the fruit bars with different formulations. It was observed that addition of ingredients generally changed the fruit bar's physical characteristics (de Menezes *et al.*, 2023). The ingredients for producing fruit bars or leathers can vary and may include sugars (Demarchi *et al.*, 2013), hydrocolloids (Singh *et al.*, 2003), acids (Saidi *et al.*, 2020), antioxidants (Gujral and Khanna, 2002), and preservatives (Vatthanakul *et al.*, 2010). It can also affect the texture (Phimpharian *et al.*, 2011) and drying duration (Zahir *et al.*, 2013). The inclusion of sugars primarily impacts the organoleptic properties and flavor of the products, whereas hydrocolloids mainly affect the texture. The addition of sugars to fruit leathers has been documented by various authors (Phimpharian *et al.*, 2011, Vatthanakul *et al.*, 2010, Gujral and Khanna, 2002, 2002) and is linked to higher total soluble solids and sweetness levels (Offia-Olua *et al.*, 2015). Further, incorporation of sucrose, pectin, and maltodextrin reduced the drying rate of mango leather (Siddiq *et al.*, 2017). The ingredients can also impact the glass transition temperature, thereby affecting the texture properties resulting into a translucent appearance (de Menezes *et al.*, 2023).

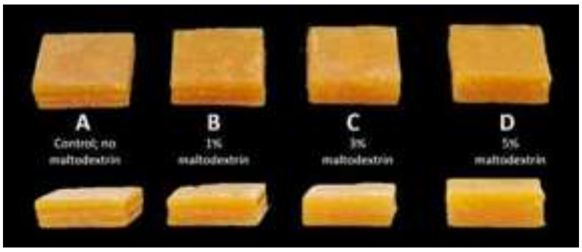

Fig. 2. Final appearance of mango fruit bars with different levels of maltodextrin

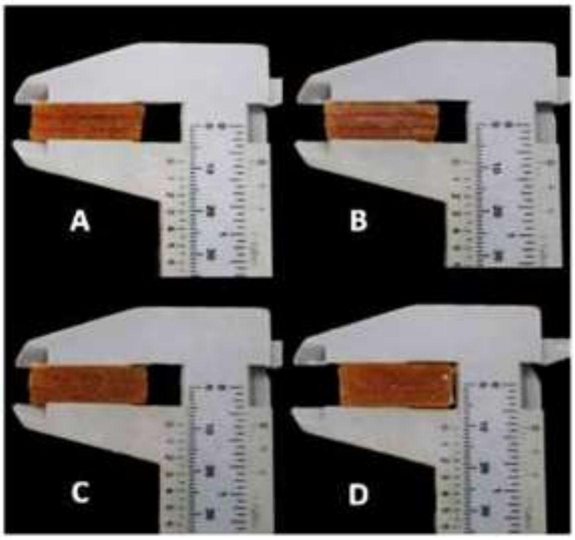

Fig. 3. Thickness (in mm) of mango fruit bars with different levels of maltodextrin; A(control), B(1%), C(3%), and D (5%)

Table 2. Thickness (in mm) of mango fruit bars as affected by increasing levels of maltodextrin

Mango fruit bar formulation	Thickness in (mm)
A (no maltodextrin)	8.26^{c}
B (1% maltodextrin)	8.51^{c}
C (3% maltodextrin)	9.38^{b}
D (5% maltodextrin)	10.63^{a}

The thickness of the fruit bar samples across different formulations was measured using a Vernier caliper (Fig. 3). Table 2 illustrates the effect of various maltodextrin concentrations on the thickness of mango fruit bars. Samples without added maltodextrin and those with 1% maltodextrin displayed similar thicknesses of 8.26 mm and 8.81 mm, respectively, with no significant difference between them. In contrast, fruit bars formulated with 3% maltodextrin showed a notable increase in thickness to 9.38 mm, while those with 5% maltodextrin reached the highest thickness of 10.63 mm. This demonstrates that higher concentrations of maltodextrin, particularly at 3% and 5%, significantly enhance the thickness of mango fruit bars. In general, increasing the concentration of maltodextrin in formulations enhances the thickness of products, such as fruit bars. Maltodextrin, typically sourced from cornstarch, serves multiple functions, including acting as a bodying or bulking agent, texturizer, carrier, and inhibitor of sugar crystallization (Saulo, 2002).

Several studies have highlighted the influence of maltodextrin on the physical properties of fruit bars. Gujral and Khanna (2002) examined how the addition of sucrose, pectin, and maltodextrin affected moisture diffusion in pineapple and mango leathers. They discovered that at maximum concentrations of 10% sucrose, 2% pectin, and 5% maltodextrin, the drying rate decreased. This reduction was attributed to an increase in total soluble solids and stronger bonds among water molecules. In addition, Valenzuela *et al.* (2015) found that adding maltodextrin to apple leathers led to reduced adhesion force and some cohesive failure, while the inclusion of glucose enhanced adhesion force.

Sensory evaluation of mango fruit bars

The primary goal of sensory analysis for fruit leathers is to assess their attributes and overall preference in order to identify the best formulation (Torres *et al.*, 2015). Sensory attributes were considered quality indicators for the final product (Concha-Meyer *et al.*, 2016). Most studies focused on the sensory acceptability of fruit leathers and, as a result, examined how the compositions of the leathers affected their sensory attributes. The sensory attributes most frequently studied in fruit leathers or bars, as noted in the literature, include color, taste, flavor, and texture. Huang and Hsieh (2005) found that the most notable sensory characteristics of fruit leathers or bars are a shiny surface, sweet and tart flavors, and appealing aromas.

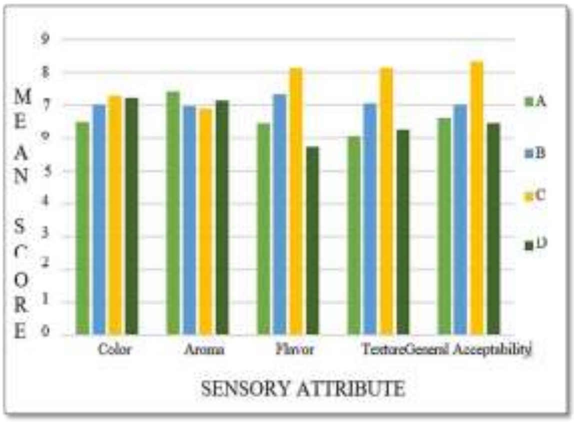

Fig. 4. Comparison of the mean scores, per attribute, of mango fruit bar with maltodextrin A(control), B(1%), C(3%), and D (5%)

A panel of 25 judges rated the color, aroma, flavour, texture, and general acceptability of fruit bar from mango in the various concentrations of maltodextrin. Table 3 presents the mean scores for the sensory attributes of the fruit bars, while Fig. 4 compares these mean scores across different formulations.

Color

Consumers often use color as a key indicator of product quality, even in the absence of direct interaction with the product (Failla *et al.*, 2008). Fruit bars across formulations exhibited from orange dark yellow color. As shown in Table 3, samples B, C, and D had similarly higher scores and were significantly different from sample A. Sample C secured the highest mean score of 7.28 and ranked as “Like Moderately” to “Like Very Much”, while sample

A obtained the lowest score of 6.68 and ranked between "Like Slighlty" to "Like Moderately".

This decline can be attributed to the effect of temperature on the sugar content of the raw material, which triggered caramelization. This process results in a decrease in product lightness, ultimately leading to a darker color (Salleh *et al.*, 2017).

The color of a substance is influenced by several pigments, including chlorophyll, carotenoids, anthocyanins, and myoglobin. However, carotenoids are highly unsaturated compounds that are susceptible to oxidation and degradation during processing and storage under chemical, mechanical, and thermal stresses (Mao *et al.*, 2009). The acceptable color of the dried product might be due to sodium metabisulfite treatment and fast drying of material under the cabinet drier. Foods such as baked goods, jams, wines, dried fruit, and many sauces are widely preserved using sodium metabisulfite. (Diamante *et al.*, 2014).

Table 3. Mean sensory scores of the different formulations of mango fruit bar

Sensory attributes	Control (No maltodextrin)	A (1% Maltodextrin)	B (3% Maltodextrin)	C (5% Maltodextrin)
Color	6.48^{a}	7.00^{b}	7.28^{b}	7.20^{b}
Aroma	7.40^{a}	6.96^{a}	6.88^{a}	7.12^{a}
Flavor	6.44^{b}	7.32^{c}	8.12^{d}	5.72^{a}
Texture (Chewiness)	6.04^{a}	7.04^{b}	8.12^{c}	6.24^{a}
General Acceptability	6.60^{ab}	7.00^{b}	8.32^{c}	6.44^{a}

Means followed by the same letter within a row are not significantly different at $p < 0.05$.

Range of the hedonic scale: 1 = Dislike extremely; 2 = Dislike very much; 3 = Dislike moderately; 4 = Dislike slightly; 5 = Neither like nor dislike; 6 = Like slightly; 7 = Like moderately; 8 = Like very much; 9 = Like extremely.

Aroma

In determining the overall acceptability of a food product, aroma is of considerable importance (Villarin *et al.*, 2021). Table 3 shows the acceptability of the aroma of mango fruit bars added with maldodextrin. Results revealed that the scores for aroma among all sample did not vary significantly. These observations was due to the aromatic characteristics of mango fruit and sugary aroma of the confectionery samples resulting to desirable and acceptable aroma. The highest mean scores, 7.40, was obtained by sample A, while the lowest mean score, 6.88, was obtained by sample C. Based on the scores, panellists rated all samples from like slightly to like very much.

Flavor

The flavor of fruit leathers or bars comes from the sugar content in the pulp of fresh fruit (Offia-Olua *et al.*, 2015). The sweetness of the leather differs based on the fruit type and storage duration (Ashaye *et al.*, 2005). Acids in food affect nutritional value and flavor, enhancing taste and shine while also boosting stability and consistency (Offia-Olua *et al.*, 2015). The combination of acids and sugars produces a pleasing taste sensation, which is detected by specialized taste buds (Safdar *et al.*, 2014).

The flavour acceptability of mango fruit bar samples is shown in Table 3. Results showed that samples from all formulations significantly differ from each other. It was observed that sample C, with 3% maltodextrin addition, was most preferred by the panelists, which gave the highest mean score of 8.12. It was followed by sample B with mean score of 7.32, then sample A with mean score of 6.44, and the least was sample D, with a mean score of 5.72. The scores of samples C and D indicated that panellists liked them very much to extremely and neither like nor dislike to slightly, respectively.

The flavour indicates that the mango fruit bar produced is a sweet and sour mango, indicating the mango's sweetness due to fruit sugar, namely fructose. In contrast, the sour taste in mangoes is due to organic acids contained in the mango flesh and the citric acid added (Akhtar *et al.*, 2009).

Texture

Texture analysis is a crucial aspect of fruit bars and leathers, encompassing hardness and fracture properties (Ayalew *et al.*, 2020). Texture attributes significantly influence consumer acceptance of a new product (Basumatary *et al.*, 2020). Generally, fruit leathers and bars are flavorful, chewy, high in fiber and carbohydrates, and easy to handle (Basumatary *et al.*, 2020). They should have a soft texture, which can be achieved by increasing moisture content while maintaining lower water activity for microbiological stability (Diamante *et al.*, 2014).

Maltodextrins are widely used as functional food ingredients and can contribute to bulking, binding, and texture development. In confectionery and related products, they can improve chewiness and provide a desirable chewy texture (BeMiller, 2003).

It can be seen from Table 3 that higher rating scales were given by the panelists to samples with 1% and 3% bulking agent, while lower scores were given to fruit bars with no maltodextrin and 5% maltodextrin. Results also revealed that mango fruit bar samples with 3% maltodextrin was the most preferred by the panelists, and was significantly different from other samples. Obtained means score were 8.12 from sample C, 7.04 from sample B, 6.24 from sample D, and 6.04 from sample A. Sample C was ranked as Like Very Much to Like Extremely, while sample A and D were both ranked as Like Slightly to Like Moderately.

Studies revealed that the texture of mango leather was also improved by incorporating gum arabic, maltodextrin, pectin, and carboxymethylcellulose (Sanchez *et al.*, 2018). A similar effect was observed with the addition of pectin to leathers made with concentrated pear juice, where a lower concentration of pectin (16%) produced soft leathers that appealed to consumers (Huang *et al.*, 2005). Furthermore, Phimpharian *et al.* (2011) found that pineapple leathers with the highest levels of glucose syrup (6%) and the lowest levels of pectin (0.5-1%) were preferred by judges, who favored softer, moister, and sweeter leathers.

General acceptability

The overall acceptability of the product is general assessment of the perception of the consumers (Villarin *et al.*, 2021). Table 3 shows the overall acceptability of mango fruit bar samples added with deiferrent levels of maltodextrin. Results revealed that sample C, with 3% maltodextrin, did differ significantly among samples A, B, and D, and was most preferred by the panelists with a acceptability mean score of 8.32 corresponding to a scale of in between Like very Much and Like Extremely. Least acceptability score was obtained by sample D, 6.44, but not significantly different from sample A, 6.60. Sample A, however, did not differ significantly from sample B, which had a mean score of, 7.00.

Visual examination by consumers plays a crucial role in determining the suitability of any food for consumption, and this is particularly true for mango fruit bars, where color is a key quality parameter. The interaction of organic acids and sugars with specialized taste buds on the tongue creates distinct taste sensations, with sweetness from sugars and sourness from organic acids being dominant flavors in many fruits. However, the addition of sugar must be carefully controlled; excessive sugar can leave the leather tacky after drying. The incorporation of citric acid and sodium metabisulfite contributes to higher acceptance scores for color and sourness. Citric acid is commonly used as a pre-treatment for mangoes to prevent browning when exposed to air. In this study, citric acid was added to lower the pH of the puree, inhibiting microbial growth during drying, as most microorganisms thrive at pH levels around 7.0 (Akhtar *et al.*, 2009). Sodium metabisulfite is an effective method for extending the shelf life of dehydrated fruits by slowing oxidation and browning. In addition to preventing browning, it also eliminates harmful bacteria during cabinet drying, including Escherichia coli O157, Salmonella, and Listeria monocytogenes (Ismail *et al.*, 2012).

The acceptability of dehydrated products largely depends on their sensory attributes. Alongside color, factors such as sweetness, sourness, and texture significantly influence consumer preferences. The favorable color of the dried product may be attributed to sodium metabisulfite treatment and the rapid drying process in the cabinet drier (Diamante *et al.*, 2014). Results indicated that mango fruit bar samples with 3% maltodextrin were the most preferred by panelists, showing significant differences from other samples. The incorporation of maltodextrin may improve the textural characteristics of mango fruit bars by functioning as a bulking and texturizing agent, thereby contributing to a more desirable mouthfeel (BeMiller, 2003).

Table 4. Proximate composition and vitamin C content of mango fruit bars with and without maltodextrin (control)

Parameter	Without maltodextrin	With 3% maltodextrin	*p*-value
Moisture (%)	15.050 ± 0.354^{a}	15.250 ± 0.354^{a}	0.629
Ash (%)	0.997 ± 0.004^{b}	1.455 ± 0.007^{a}	<0.001
Fat (%)	2.655 ± 0.050^{a}	2.220 ± 0.028^{b}	0.008
Protein (%)	1.850 ± 0.014^{b}	2.495 ± 0.007^{a}	<0.001
Carbohydrates (%)	79.450 ± 0.396^{a}	78.580 ± 0.382^{a}	0.155
Total Dietary Fiber (%)	2.965 ± 0.063^{b}	3.775 ± 0.050^{a}	0.005
Vitamin C (mg/100 g)	34.790 ± 1.600^{b}	40.350 ± 0.651^{a}	0.045

Values are expressed as mean ± standard deviation. Means within the same row with different superscript letters are significantly different at $p < 0.05$.

Proximate composition and vitamin C content of mango fruit bars

Table 4 shows the proximate composition and vitamin C content of mango fruit bars formulated with 3% maltodextrin and the control formulation without maltodextrin. The results revealed that the incorporation of 3% maltodextrin significantly affected several nutritional parameters of the mango fruit bars. Specifically, the mango fruit bars with 3% maltodextrin exhibited significantly higher ash (1.455%), protein (2.495%), total dietary fiber (3.775%), and vitamin C (40.350 mg/100 g) contents than the control formulation, which contained 0.997% ash, 1.850% protein, 2.965% dietary fiber, and 34.790 mg/100 g vitamin C, respectively ($p < 0.05$).

The significantly higher ash content suggests greater mineral retention in the mango fruit bars containing maltodextrin. Likewise, the higher protein and total dietary fiber contents indicate that the incorporation of maltodextrin improved the nutritional quality of the product while helping maintain the integrity of the fruit matrix during drying. Maltodextrin functions as a carrier and bulking agent that stabilizes food solids during dehydration, thereby minimizing nutrient degradation and improving the stability of dried fruit products (Mahendran, 2010).

Similarly, Tiwari (2019) reported that fruit bars produced from fruit pulp generally retain considerable amounts of naturally occurring vitamins, minerals, and dietary fiber, making them nutritious and functional snack products. Furthermore, Jantanasakul *et al.* (2019) demonstrated that the incorporation of maltodextrin in fruit leather formulations contributed to improved drying characteristics and desirable product quality, supporting its application in dehydrated fruit products.

In contrast, the control mango fruit bars contained significantly higher fat content (2.655%) than the mango fruit bars with 3% maltodextrin (2.220%) ($p = 0.008$). Although this difference was statistically significant, both formulations remained relatively low in fat, indicating that the addition of maltodextrin did not adversely affect the nutritional profile of the product. The lower fat content observed in the maltodextrin-containing fruit bars may also reflect the dilution effect of the added carbohydrate-based carrier without compromising the overall nutritional value.

No significant differences were observed in moisture and carbohydrate contents between the two formulations ($p > 0.05$). The moisture contents of approximately 15% indicate that both fruit bar formulations achieved similar drying endpoints. This moisture level is within the recommended range for fruit leather products, which generally contain less than 20% moisture to ensure desirable texture, reduced water activity, and improved storage stability (Jantanasakul *et al.*, 2019; Tiwari, 2019). The absence of significant differences in carbohydrate content likewise indicates that the incorporation of 3% maltodextrin did not substantially alter the overall carbohydrate composition of the mango fruit bars.

The mango fruit bars with 3% maltodextrin also retained significantly higher vitamin C than the control formulation. Since vitamin C is highly susceptible to degradation during heat processing and oxidation, the higher concentration observed in the maltodextrin-containing fruit bars suggests that maltodextrin provided a protective effect during dehydration.

Mahendran (2010) similarly reported that maltodextrin improves the retention of ascorbic acid and other quality attributes by protecting sensitive compounds during drying. In addition, Tiwari (2019) emphasized that appropriate drying techniques and formulation strategies are essential for minimizing nutrient losses and preserving the nutritional quality of fruit bars.

Overall, the incorporation of 3% maltodextrin enhanced the nutritional quality of the mango fruit bars by increasing mineral content, protein, dietary fiber, and vitamin C while maintaining comparable moisture and carbohydrate contents relative to the control formulation. These findings demonstrate that maltodextrin can be effectively utilized as a functional ingredient in mango fruit bar production to improve nutrient retention, product stability, and overall quality. The results are consistent with previous studies highlighting the role of maltodextrin in enhancing the physicochemical and nutritional properties of dehydrated fruit products (Mahendran, 2010; Jantanasakul *et al.*, 2019; Tiwari, 2019).

CONCLUSION

This study demonstrated the potential of adding value to mango, a highly perishable fruit, through the development of mango fruit bars using maltodextrin as a bulking agent. The results showed that the incorporation of maltodextrin significantly influenced the physical, nutritional, and sensory characteristics of the product, confirming its effectiveness as a functional ingredient in mango fruit bar production. Among the formulations evaluated, the fruit bars containing 3% maltodextrin exhibited the most desirable combination of quality attributes.

The addition of maltodextrin significantly improved the physical properties of the mango fruit bars by increasing their thickness, with the 3% and 5% maltodextrin formulations producing thicknesses of 9.38 mm and 10.63 mm, respectively. These findings indicate that increasing the concentration of maltodextrin enhances the structural integrity and body of the fruit bars. Sensory evaluation further revealed that the formulation containing 3% maltodextrin received the highest acceptability ratings, particularly for texture, flavor, and overall acceptability. The incorporation of sugar, citric acid, and sodium metabisulfite, together with drying at 55°C for 17 hours, contributed to the desirable sensory characteristics of the final product.

The proximate composition analysis further demonstrated the nutritional benefits of incorporating 3% maltodextrin into mango fruit bars. Compared with the control formulation, the fruit bars containing 3% maltodextrin had significantly higher ash, protein, total dietary fiber, and vitamin C contents while maintaining comparable moisture and carbohydrate levels. Although the control formulation exhibited slightly higher fat content, both formulations remained low in fat. These findings indicate that maltodextrin not only improved the physical characteristics of the fruit bars but also enhanced nutrient retention during processing, resulting in a product with improved nutritional quality.

Overall, the findings identified 3% maltodextrin as the optimum level for producing mango fruit bars with desirable physical properties, enhanced nutritional composition, and high consumer acceptability. The developed product has strong potential as a nutritious value-added snack that can help reduce postharvest losses, increase the utilization of surplus mangoes, and create additional income opportunities for mango producers and food processors.

Based on the findings of this study, the formulation containing 3% maltodextrin is recommended for the production of mango fruit bars because it provided the best balance of physical properties, nutritional quality, and consumer acceptability. Future studies should investigate the shelf life, microbial stability, water activity, packaging systems, and storage conditions of the product to establish its commercial viability and determine its storage stability. Further research is also recommended to evaluate different concentrations and combinations of maltodextrin with other bulking or carrier agents and to determine their effects on the physicochemical, nutritional, and sensory properties of mango fruit bars. In addition, the determination of bioactive compounds such as carotenoids, total phenolics, and antioxidant activity is recommended to further establish the functional value of the product.

Finally, economic feasibility, consumer market acceptance, and pilot-scale production studies should be conducted to assess the commercial potential of mango fruit bars and facilitate their adoption by the food processing industry and local mango producers.

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