Production and Evaluation of the Physico-chemical and Sensory Attributes of Watermelon Fruit Leather and Sauce

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Abstract: Processing watermelon (*Citrullus lanatus*) is crucial for minimizing post-harvest losses, and exploring fruit leather and sauce development offers a promising strategy to diversify processed products. This research investigates the impact of different corn flour concentrations (T_1: 1% corn flour, T_2: 1.25% corn flour, and T_3: 1.50% corn flour) on watermelon-based products, sauce and leather, over a nine-month storage period. Employing a Completely Randomized Design with three replications, high-quality Dragon King Variety watermelons were processed into sauce and leather. Physicochemical and quality parameters were assessed at 3-month intervals. Microbial changes were analyzed for *E. coli* and fungal growth, and sensory evaluation involved 15 panelists using a 9-point hedonic scale. Results highlighted the significant influence of corn flour concentrations, with T_2 (1.25% corn flour) exhibiting superlative outcomes across an array of parameters, including color, firmness, pH, titratable acidity (TA), total anthocyanin, total carotene, total antioxidant, total phenol, total carbohydrate, total sugar, and reducing sugar content. Watermelon leather outperformed sauce in key attributes such as pH, total soluble solids (TSS), TA, total anthocyanin, total carotenoids, total antioxidant, total phenol, total carbohydrate, total sugar, and reducing sugar content, and microbial analyses revealed the absence of *E. coli* and fungal growth in watermelon leather, in contrast to sauce. Treatment T_2 (corn flour 1.25%) exhibited optimal performance, with no *E. coli* colonies or fungal growth. Sensory evaluation unequivocally favored watermelon leather over sauce, with T_2 receiving the highest acclaim. This study elucidates the significant influence of corn flour concentration on the quality, physicochemical, microbial, and sensory attributes of watermelon sauce and leather during storage, offering strategic insights for product development and shelf-life optimization in the food processing industry.

Keywords: Watermelon fruit leather, sauce, physicochemical attributes, sensory properties.

Introduction

Watermelon (*Citrullus lanatus*), a member of the Cucurbitaceae family, is native to tropical Africa and is widely enjoyed as a refreshing fruit, particularly during hot summer weather. Global watermelon production reached 200.20 million tons in 2020 (FAO, 2021a). In Bangladesh, the total fruit cultivation area in 2013-2014 was approximately 1,785,000 acres, yielding a production of 8,857,000 metric tons (BBS, 2021). Watermelon specifically occupied an area of about 40,860.73 acres, resulting in a production of 345,955.44 metric tons (BBS, 2021). Among the watermelon-growing districts during that period, the Patuakhali district contributed 2,555.38 metric tons from 1,094 acres of land (BBS, 2021). Watermelon is known for its high citrulline and amino acid content, which the human body utilizes to produce arginine, an amino acid involved in the urea cycle for removing nitrogenous waste. It ranks as the third most popular fruit globally and offers a significant nutrient profile (Zhu et al., 2017). The lipid content of watermelon is rich in linoleic and oleic acids, while the protein content is notable for its abundance of arginine, glutamic acid, and leucine amino acids (El-Adawy et al., 2001).

Despite efforts to extend the shelf life of watermelon using ambient postharvest facilities, it can only be increased by about one month. As a seasonal fruit, watermelon is only available during its season, and its short shelf life prevents availability during off-season periods. Approximately one-third of the world's annual production of fruits and vegetables goes to waste due to postharvest losses, and watermelon is no exception (Kader, 2005). Storage-related issues, such as rotting and physiological disorders like bruising and sun scorching, result in significant losses for watermelon, with 17% being lost during storage and over 50% due to these disorders (Lamptey, 2010). Due to the short harvest season and sensitivity to deterioration, most fresh fruits tend to lose their quality even when stored under refrigerated conditions. Consequently, the production of fruit leather and sauce from fresh fruits represents an effective preservation method (Maskan et al., 2002). To address this issue and meet consumer demand year-round, the production of processed watermelon products has gained interest.

Various processed fruit products, such as juice, sauce, jam, jelly, and leather, exist, with sauce and leather being the oldest and most commonly used preservation methods in the fruit processing industry. These methods involve reducing the water content in fresh fruits to inhibit enzymatic and microbial activities, thereby preventing deterioration (Teshome, 2010). Fruit leathers are a type of restructured fruit, created by using fresh fruit pulp or a mixture of fruit juice and other ingredients. The process involves dehydration, resulting in visually appealing and flexible sheets that maintain their shape. Fruit leathers are commonly consumed as snacks or desserts (Chang et al., 2009). On the other hand, fruit sauce refers to a puree made from fruits. Leathers are not only nutritious and flavorful but also retain significant amounts of minerals, vitamins, and phenolic phytochemicals that are naturally present in the raw materials (Diamante et al., 2014). These products are lightweight, enjoyable to chew, and delicious, making them an enticing way to incorporate fruit into one's diet, particularly for children and adolescents (Quintero et al., 2012). Currently, they have gained popularity in the health food market, leading to the utilization of various formulations in their production (Vatthanakul et al., 2010). Corn flour holds significant importance in various industrial applications, playing a crucial role in moisture retention, inhibiting sugar crystal formation, and augmenting juiciness (Ali et al., 2016). Notably, in the preparation of mango leather, Bandaru et al. (2020) employed corn flour to thicken the puree. The inherent capacity of starch to undergo reactions with itself or other compounds renders it versatile in food systems, serving as a thickener, gelling agent, stabilizing agent, or filler (Tiwari et al., 2019; Alimi et al., 2017; Gilbert et al., 2013). Despite these diverse applications, there exists a research gap in the development and storage methodologies for watermelon processed products, limiting their availability throughout the year.

Hence, undertaking a comprehensive analysis of the formulation and assessment of the physicochemical attributes of watermelon sauce and leather becomes imperative for discerning the optimal techniques for the production and storage of processed watermelon products. In light of these objectives, this investigation is designed to generate and scrutinize the physicochemical and sensory profiles of watermelon sauce and leather throughout storage.

Materials and Methods

The experiment encompassed two factors: Factor A, comprising two watermelon processed products, namely sauce and leather; and Factor B, encompassing three experimental treatments of corn flour concentrations denoted as T1 = 1% corn flour, T2 = 1.25% corn flour, and T3 = 1.50% corn flour. Both the sauce and leather were meticulously prepared utilizing the three distinct corn flour concentrations. The experimental design adopted was a Completely Randomized Design (CRD) with three replications, wherein treatments were randomly allocated within each replication. Commencing at the onset of the storage period, data collection transpired at 3-month intervals, culminating in a 9-month duration. Subsequently, the amassed data on diverse parameters underwent meticulous statistical scrutiny using the MSTAT-C software package developed by the Crop and Soil Sciences Department of Michigan State University in the United States. Analysis of variance (ANOVA) was executed, and distinctions in means were delineated through Duncan's Multiple Range Test (DMRT) (Gomez & Gomez, 1984) at a 5% level of probability.

High-quality Dragon King Variety fruits (Syngenta Ltd.), exhibiting uniformity in size, shape, and maturity, were sourced from the local market. These fruits, ranging from medium to large sizes and weighing approximately 4-5 kg, were subjected to a meticulous cleaning process involving washing with running tap water, followed by a rinse with sterile double-distilled water. After this, the fruits were skillfully cut into small pieces, and the pulp was meticulously extracted using a knife. The extracted pulp underwent further processing through blending, achieved with the assistance of an electric blender. Initial assessment revealed a relatively low brix percentage in the blended watermelon pulp. To augment ‘the brix percentage, the pulp underwent a controlled heating process at 2000 watts for 1 hour, employing an induction cooker (Fig. 1). To craft watermelon sauce, a blend of sugar (35 g), varied concentrations of corn flour (1%, 1.25%, and 1.50%), and citric acid (5.75 g) was meticulously combined with each kilogram of watermelon pulp.

This amalgamation underwent controlled heating at 500 watts until achieving a brix percentage of 60%. The resultant watermelon puree (Fig. 2A) was carefully stored in glass jars, serving as the foundation for the watermelon sauce (Fig. 2B).

For the production of watermelon leather, 200 grams of the processed watermelon puree were uniformly sprayed onto stainless steel trays utilizing a metal spreader. The thickness and color of each sample were methodically measured, and the trays were left at room temperature for 10 minutes. Subsequently, the cabinet dryer (BARI hybrid dryer) was preheated to 70 °C, and the puree underwent a drying period of 10 hours within the middle compartment. The dryness of the emerging watermelon leather (Fig. 2C) was consistently monitored throughout the drying phase. Upon achieving the desired dryness, the watermelon leather was meticulously packaged in polyethylene packets. In this study, watermelon fruits were processed following the method outlined by Singh et al. (2019) with some modifications. The flow diagram of the watermelon sauce and puree preparation are shown in figure 1. Data was collected on the following parameters-

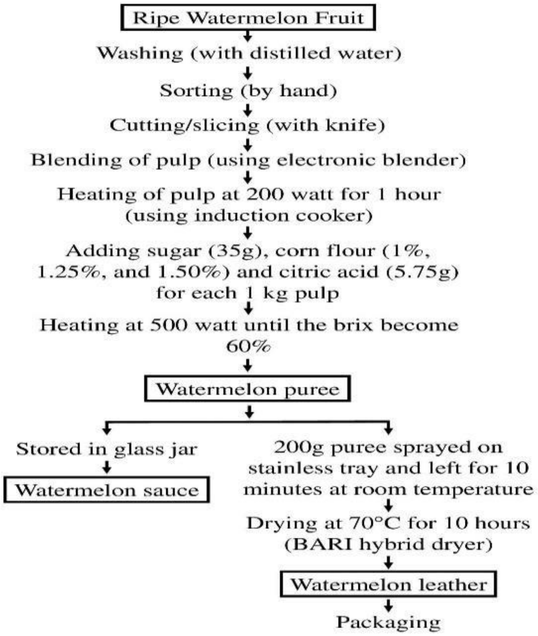

Figure 1. A schematic diagram of the general process for producing watermelon fruit sauce and leather.

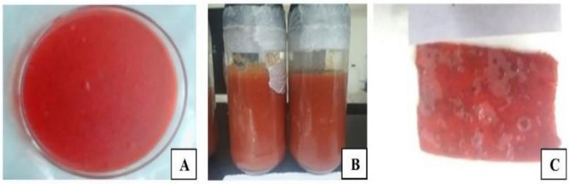

Figure 2. Watermelon puree (A); Sauce (B) and leather (C).

Weight loss was determined with a top pan electronic balance (BP 2100, Sartorius, Germany). The percentage of weight loss was calculated using the following formula:

$$\text{Weight loss (\%)} = \frac{W_{1}-W_{n}}{W1} \times 100$$

Where, W1 = Initial weight. Wn = Final weight.

Firmness was measured using a digital fruit firmness testing machine (Model GY-802) and expressed in newtons (N). The peel color was determined using an Android application software called "On Color Measure" (developed by Potato Tree Soft, Version 3.0). The color determination was expressed as chromaticity values of Red (R*), Green (G*), and Blue (B*) in RGB percentages. The pH was determined using a glass electrode pH meter (GLP 21, Crison, Barcelona, and EEC). The concentration of total soluble solids (TSS) was determined using a digital refractometer (Model N-1 α, Atago, Japan) and expressed as a percentage. Titratable acidity (TA) was determined following the method described by Ranganna (1979) and expressed as a percentage. Total anthocyanin content was determined according to the method of Sims et al. (2002) and expressed in micrograms per gram (µg/g). Total carotenoid content was determined using the method of Sims et al. (2002) and expressed in µg/g. The total antioxidant activity was determined using the phospho-molybdenum method with some modifications as described by Alakh et al. (2011) and expressed in µg/g. The total phenolic content was determined following a modified method based on Chanda et al. (2009) and expressed in milligrams per 100 grams.

Total soluble carbohydrate content was estimated using the phenol-sulfuric acid method described by Dubois et al. (1956) and expressed in grams per 100 grams. Total sugar content was determined using the method of Lane and Eynon (1923) and expressed in grams per 100 grams. Reducing sugar content was also determined using the method of Lane and Eynon (1923) and expressed in grams per 100 grams.

To study microbial changes, the watermelon leather was cut into 5 × 3 mm pieces using a sterile knife. Then, a 50 g sample was soaked in 100 ml of sterilized water and shaken at 100 rpm for 24 hours at room temperature (28 ± 2 °C). Serial dilutions (10^{-1}-10^{-6}) of the suspension were prepared in test tubes. For the sauce, a 10 g sample was soaked in 20 ml of sterilized water, and serial dilutions (10^{-1}-10^{-6}) of the suspension were made in test tubes. Subsequently, 100 µl of the suspensions from each test tube was spread onto VRBA (Violet Red Bile Agar) medium using a sterile glass rod and incubated for 96 hours at 28 ± 2 °C. After 4 days (96 hours), the samples were observed for bacterial analysis.

A sensory trial to evaluate consumer acceptability was conducted at the Department of Horticulture, Patuakhali Science and Technology University (PSTU). The panelists comprised 15 volunteers, including students and faculty members from the university. The panelists were provided with guidance on conducting sensory evaluations of watermelon leather and sauce. Each panelist tasted both the watermelon sauce and leather samples. The samples were evaluated based on various characteristics, including color, overall appearance, texture (perception, stickiness, and chewiness), sweetness, flavor, and overall acceptability. To assess their preference, a 9-point hedonic scale, as described by Ihekoronye & Ngoddy (1985), was used. The panelists ranked their responses on a scale of 1 to 9, with 9 indicating "like extremely" and 1 indicating "dislike extremely." Additionally, the panelists were asked three additional questions to determine their liking of the fruit leathers and sauce, and which product they would prefer to buy. The responses obtained were analyzed using one-way ANOVA to determine any statistical differences.

Results and Discussion

Weight loss of watermelon leather

Significant variations in weight loss were noted among the distinct treatments applied to watermelon leather (Table 1). The treatment designated as T_2 (1.25% corn flour) exhibited the highest weight loss at 81.41%, in contrast to the lowest weight loss of 79.25% observed in T_3 (1.50% corn flour). The decline in the leather's weight can be ascribed to the likely occurrence of water loss during the drying process, a phenomenon further accelerated by the application of elevated temperatures. This weight loss was notably observed by Fulchand et al. (2015), who documented a significant reduction in the moisture content of fruit leather stored in various packaging materials.

Firmness of watermelon leather

Significant variations were noted in the fruit firmness of watermelon leather among different treatments (Table 1). The highest firmness, measuring 4.46 N, was recorded in watermelon leather prepared with 1.25% corn flour (T_2), whereas the lowest firmness, amounting to 3.4 N, was found in the 1% corn flour (T_1) treated leather. The retention of firmness in watermelon leather could be ascribed to the lower weight losses, aligning with findings in studies on strawberries (Del Valle et al., 2005), apples (Moldao Martins et al., 2003), and sweet cherries (Yaman & Bayindirh, 2002), where various edible coatings, such as yam starch, cactus mucilage, alginate, gelatin, and simply fresh, contributed to maintaining firmness.

Table 1. Weight loss (%) and firmness of watermelon leathers during drying

Treatments	Weight Loss (%)	Firmness
T_1	79.61^b	3.29^c
T_2	81.41^a	4.46^a
T_3	79.25^b	3.89^b
CV (%)	1.06	4.54
Level of	**	*

In the column, values having a similar letter (s) are statistically identical and those having the dissimilar letter (s) differ significantly at 1% level of probability analyzed by DMRT. **= Significant at 1% level; *= Significant at 5% level. T_1 = corn flour 1%; T_2= corn flour 1.25% and T_3= corn flour 1.50%.

Color

No significant differences were detected in the variations of red, green, and blue (RGB) color values among the treatments (Fig. 3). The highest red color value (58%) was noted in T_2 (1.25% corn flour), while the lowest value (52%) was recorded in T_1 (1% corn flour). Color holds paramount importance

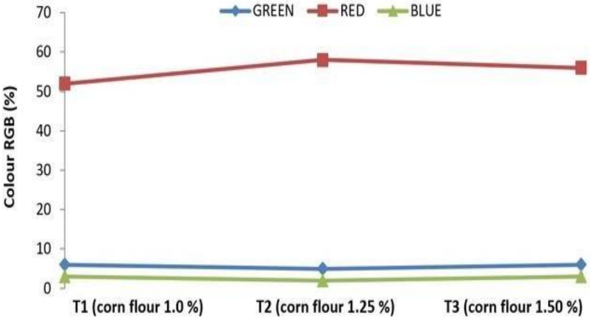

Figure 3. RGB% of watermelon leather at different treatments

as a quality criterion for watermelon, with green and blue colors being nearly absent.

The lack of green and blue colors in the final product could be attributed to heat exposure during the puree preparation process. However, color attributes change the drying process, contingent on the specific process and drying conditions (Baini & Langrish, 2009). In contrast to our findings, Umi et al. (2018) reported variations in the color parameters of *Salacca* sp. fruit leather during storage.

p^H value

The pH values displayed significant variations in both watermelon processed products (sauce and leather) and across different concentrations of corn flour during the storage period (Fig. 4A and 4B). After 9 months, the highest pH value (4.40) was recorded in watermelon leather, while the lowest pH value (4.27) was observed in the sauce. Regarding corn flour concentrations, the initial pH values at the onset of storage were significantly higher (4.49) in T3 (1.50% corn flour concentration) and lower (4.38) in T1 (1% corn flour concentration). After 9 months, the highest pH value (4.45) was noted in T2 (1.25% corn flour concentration), and the lowest (4.23) was in T1 (1% corn flour concentration).

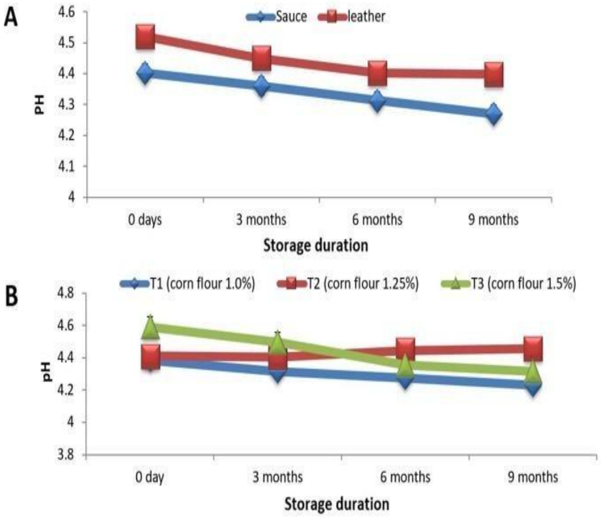

Figure 4. Effects of processed products, sauce and leather (A) and corn flour concentrations (B) on pH content of watermelon during storage. Vertical bars

A decline in pH sulfurous acid, and the generation of acids from sugars, collectively contributing to an overall rise in acidity content (Vagadia et al., 2016). Comparable observations regarding acidity variations were reported by Aruna et al. (1999) in papaya bars.

Total soluble solids (%)

Significant variations were observed in the total soluble solids (TSS) of watermelon processed products, including sauce and leather, as well as different concentrations of corn flour during storage (Figure 5A and 5B). The TSS values exhibited a decreasing trend over the storage period for watermelon processed products. After 9 months, the watermelon leather showed the highest TSS value (11.77%), while the sauce displayed the lowest TSS value (10.86%). Additionally, after 9 months of preservation, the 1.50% corn flour treatment (T3) exhibited the highest TSS value (11.33%), with the lowest value (11.28%) observed in the 1.25% corn flour treatment (T2). The changes in total soluble solids (TSS) in fruit leather are influenced by metabolic processes, especially oxidative metabolism. Prolonged storage can lead to alterations in moisture levels, causing fluctuations in the pore space of the product, resulting in either a decrease or increase in TSS due to water absorption. Similar observations were reported by Vennilla (2004) in guava-papaya fruit bars and Aruna et al. (1999) in papaya bars.

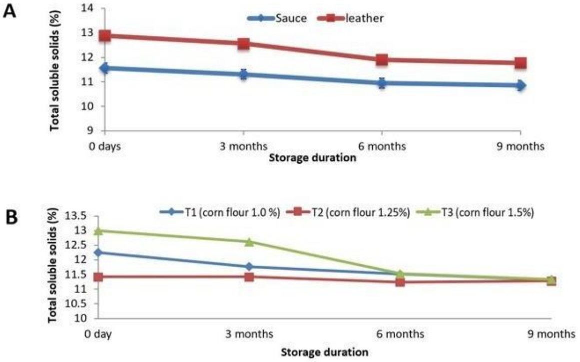

Figure 5. Effects of processed products, sauce and leather (A) and corn flour concentrations (B) on TSS content of watermelon during storage. Vertical bars represent the standard error of mean.

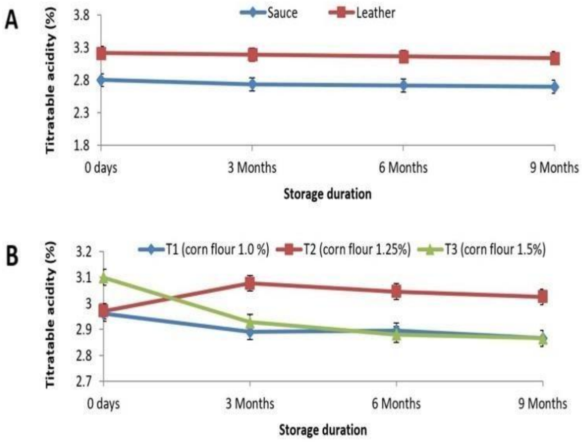

Figure 6. Effects of processed products, sauce and leather (A) and corn flour concentrations (B) on titratable acidity of watermelon during storage. Vertical bars represent the standard error of mean.

Titratable acidity (%)

Significant effects on titratable acidity (TA) were observed in watermelon processed products (sauce and leather) and various concentrations of corn flour during storage (Fig. 6A and 6B). Both processed products and corn flour concentration exhibited a decrease in titratable acidity with the progression of the storage period. After 9 months of storage, the highest TA value (3.14%) was recorded in watermelon leather, while the lowest TA value (2.70%) was observed in the sauce. Ghanta *et al.* (1994) previously reported a gradual decrease in titratable acidity in fruit pulp throughout the storage period. Among the different corn flour concentrations, the highest TA value (3.02%) was recorded in T2 (1.25% corn flour), while the lowest TA value (2.86%) was found in T3 (1.50% corn flour) and T1 (1.0% corn flour) after 9 months of storage. Titratable acidity serves as a measure of the acid content in a food product. During storage, enzymatic activities contribute to the breakdown of acids, catalyzing their hydrolysis and leading to a subsequent decrease in titratable acidity. Additionally, changes in pH, temperature, and the presence of certain compounds can contribute to the reduction in titratable acidity. These factors facilitate the formation of new compounds and the neutralization of acidity, resulting in a decrease in titratable acidity levels (Hui et al., 2006). Acids present in food not only enhance palatability but also influence nutritional value and keeping quality (Adedeji et al., 2006). El Ghaouth et al. (1997) and Garcia et al. (1998) reported a decrease in titratable acidity during storage in strawberries.

Total anthocyanin content (µg/g)

Watermelon processed products (sauce and leather) and various concentrations of corn flour demonstrated a significant effect on anthocyanin content during storage. Throughout the storage period, both processed products and corn flour concentration exhibited a gradual decrease in anthocyanin content (Fig. 7A and 7B). The leather showed the highest anthocyanin value (236.46 µg/g) after 9 months of storage, while the sauce exhibited the lowest value (234.17 µg/g). Among the treatments, corn flour at 1.25% (T2) performed the best, with an anthocyanin content of 236.85 µg/g after 9 months of storage, while the lowest anthocyanin content (234.72 µg/g) was found in T3 (corn flour 1.50%).

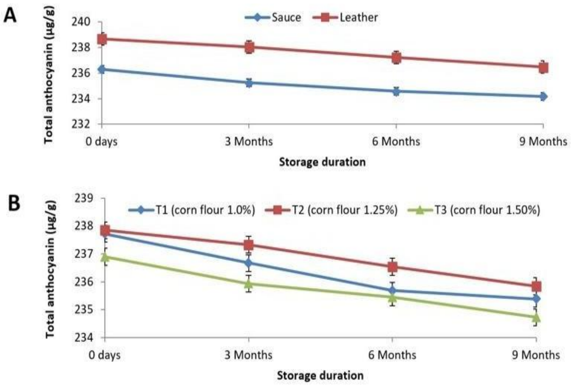

Figure 7. Effects of processed products, sauce and leather (A) and corn flour concentrations (B) on anthocyanin content of watermelon during storage. Vertical bars represent standard error. Vertical bars represent the standard error of mean.

The degradation of anthocyanins may result from non-enzymatic oxidation reactions, enzymatic reactions, and/or condensation reactions with other compounds (da Silva et al., 2022). Additionally, factors such as light exposure, temperature, and changes in pH levels, particularly towards more acidic conditions, can contribute to the degradation of anthocyanins (Giusti et al., 2003). Previous studies (Arakawa, 1991) have reported a gradual decrease in anthocyanin content in mangoes during storage.

Total carotenoids (µg/g)

Significant variations were observed in the total carotenoid content of watermelon processed products (sauce and leather) and different concentrations of corn flour during storage (Figure 8A and 8B). The carotenoid content gradually increased as the storage period progressed for both the processed products and corn flour concentrations. After 9 months, watermelon leather exhibited the highest carotenoid content (3.22 µg/g), while the sauce showed the lowest (2.97 µg/g).

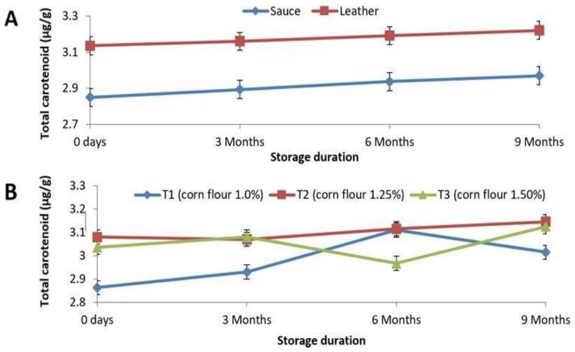

Figure 8. Effects of processed products, sauce and leather (A) and corn flour concentrations (B) on total carotenoids of watermelon during storage. Vertical bars represent standard error. Vertical bars represent the standard error of the mean.

Concerning corn flour concentration, T2 (1.25% corn flour) demonstrated the highest carotene content (3.12 µg/g), whereas T1 (1.0% corn flour) had the lowest (3.02 µg/g) after 9 months of storage. The increase in total carotenoid content in watermelon sauce and leather during storage is likely attributed to enzymatic activities, particularly phytoene synthase, which facilitates the synthesis and accumulation of carotenoids. This enzyme involved in carotenoid biosynthesis remains active and continues its catalytic functions, leading to enhanced production of carotenoids over time. Maintaining optimal storage conditions, such as moderate temperatures and reduced exposure to light and oxygen, is crucial for preserving and augmenting carotenoid levels in fruit leather (Schieber & Weber, 2016). Rakhi et al. (2021) reported a slight increase in carotene content in guava fruit leather over a 30-day storage period.

Total antioxidant content (µg/g)

A statistically significant decreasing trend was observed in the antioxidant content of watermelon processed products (sauce and leather) and different concentrations of corn flour during storage (Fig. 9A and 9B) throughout the storage period. After 9 months, watermelon leather exhibited the highest antioxidant content (154.60 µg/g), while the sauce showed the lowest (151.28 µg/g). Among the different corn flour concentrations, T2 (1.25% corn flour) demonstrated the highest antioxidant content (153.37 µg/g) after 9 months of storage, whereas T1 (1.0% corn flour) had the lowest (152.38 µg/g). The reduction in antioxidant content during the storage of fruit leather is likely due to the presence of enzymes introduced during processing, which can catalyze the degradation of antioxidants. Additionally, oxygen present in the air can react with antioxidants, leading to a decrease in their content. Furthermore, high temperatures during storage may also contribute to the reduction of antioxidants (Lavelli, 2009). The loss in antioxidant capacity might be attributed to the chemical oxidation of antioxidants through the Maillard reaction (Scala et al., 2011). A previous study conducted by Natalia et al. (2012) reported a 47% decrease in antioxidant activity during a 7-month storage period of apple leather.

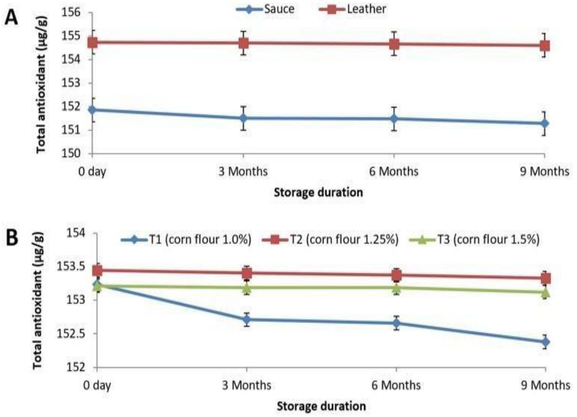

Figure 9. Effects of processed products, sauce and leather (A) and corn flour concentrations (B) on antioxidant content of watermelon during storage. Vertical bars represent the standard error of mean.

Total phenol content (mg/100g)

The total phenol content was significantly reduced by watermelon processed products (sauce and leather) and different concentrations of corn flour during storage (Fig. 10A and 10B). After 9 months, watermelon leather exhibited the highest total phenol content (22.47 mg/100g), while the sauce showed the lowest (19.7 mg/100g). Regarding the corn flour concentration treatment, the highest total phenol content (21.65 mg/100g) was found in T2 (1.25% corn flour), while the lowest (19.09 mg/100g) was found in T1 (1.0% corn flour) after 9 months of storage. The contribution of Maillard reaction products to the total phenolic and antioxidant activity may explain these findings (Zhuang & Sun, 2011). Oxidation leads to the production of free radicals, which can be neutralized by vitamins and polyphenols (Amaya-Farfan & Rodriguez-Amaya, 2021). Moreover, the drying process conditions typically exert a notable impact on the degradation of phenolic compounds, resulting in reductions ranging from 10.9% to 83.3% (Tontul & Topuz, 2017).

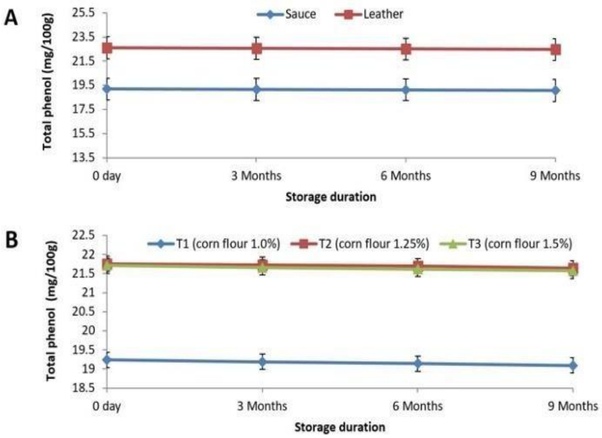

Figure 10. Effects of processed products, sauce and leather (A) and corn flour concentrations (B) on total phenol content of watermelon during storage. Vertical bars represent the standard error of mean.

Total carbohydrate content (g/100g)

The carbohydrate content of watermelon processed products (sauce and leather) and different concentrations of corn flour exhibited significant effects during storage (Fig. 11A and 11B). A gradual decrease in the carbohydrate content was observed throughout the nine-month storage period. After 9 months, watermelon leather showed the highest carbohydrate content (1.54g/100g), while the sauce exhibited the lowest value (1.07g/100g). Among the different corn flour concentrations, T2 (1.25% corn flour) had the highest carbohydrate content (1.41g/100g), while T1 (1.0% corn flour) had the lowest (1.15g/100g). The decrease in carbohydrate content during the storage of fruit leather

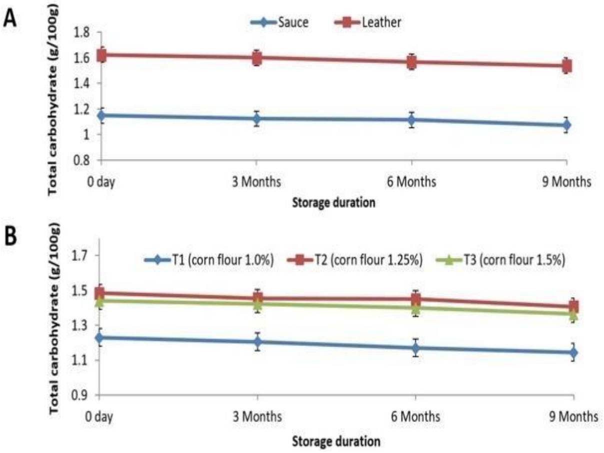

Figure 11. Effects of processed products, sauce and leather (A) and corn flour concentrations (B) on carbohydrate content of watermelon during storage. Vertical bars represent the standard error of mean.

can be attributed to factors. Enzymes introduced during processing, such as amylases, break down starch into smaller sugar molecules, leading to a reduction in carbohydrate levels. Additionally, enzymes like invertases or glucosidases can convert sugars into different forms or metabolize them, further contributing to the decrease in carbohydrate content. Moreover, Maillard reactions occur between reducing sugars and amino acids, resulting in the formation of brown pigments and the consumption of sugars. These reactions lead to a decrease in carbohydrate content and the generation of new compounds (Paravisini & Peterson, 2016). Sule & Omologbe (2017) reported a significant reduction in the carbohydrate content in pawpaw leather.

Total sugar content (g/100g)

Significant effects were observed on the total sugar content of watermelon processed products (sauce and leather) and different concentrations of corn flour during storage, as depicted in Figure 12A and 12B. After a nine-month storage period, watermelon leather exhibited the highest total sugar content (13.51g/100g), while the lowest (12.56 g/100g) was found in watermelon sauce. Regarding corn flour treatments, the corn flour concentration of 1.25% (T2) showed the highest total sugar content (13.30 g/100g), whereas the corn flour concentration of 1.0% (T1) had the lowest (12.77 g/100g). This reduction in sugar percentages may be attributed to the inversion of sugars to monosaccharides through acid hydrolysis, as suggested by Aruna et al. (1998), and the breakdown of carbohydrates (Vagadia et al., 2016). Previous research on peach fruit leathers (Anju et al., 2014) and papaya fruit leather (Vagadia et al., 2016) indicated a decrease in sugar content.

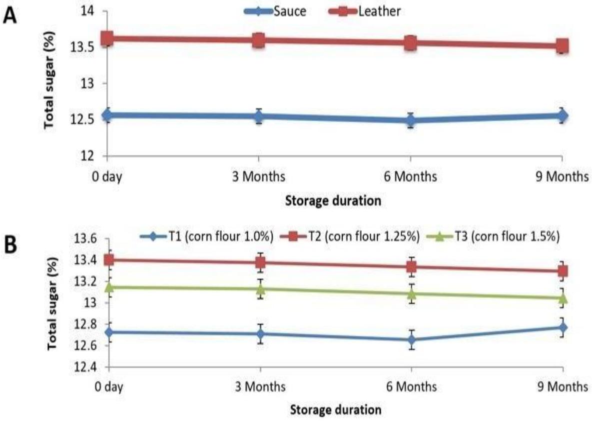

Figure 12. Effects of processed products, sauce and leather (A) and corn flour concentrations (B) on total sugar content of watermelon during storage. Vertical bars represent the standard error of mean.

Reducing sugar content (g/100g)

Statistically, a significant decreasing trend was observed in the reducing sugar content of watermelon processed products (sauce and leather) and different concentrations of corn flour during storage, as depicted in Figure 13A and 13B. After 9 months of storage, watermelon leather exhibited the highest reducing sugar content (5.09g/100g), while the lowest (4.72g/100g) was recorded in watermelon sauce. Concerning the corn flour concentration, the highest reducing sugar content (4.98 g/100g) was observed in T2 (corn flour 1.25%), while the lowest (4.85 g/100g) was observed in T1 (corn flour 1.0%) at the end of the 9- month storage period. Enzymes like invertases or glucosidases might hydrolyze the bonds in reducing sugars, converting them into other forms or metabolizing them for energy. Our results were confirmed by Paravisini & Peterson (2016), who reported the decomposition of sugars under acidic conditions to form reactive intermediates. Major mechanisms, including ascorbic acid degradation, acid-catalyzed sugar degradation, Maillard browning reactions, and caramelization can also occur during storage.

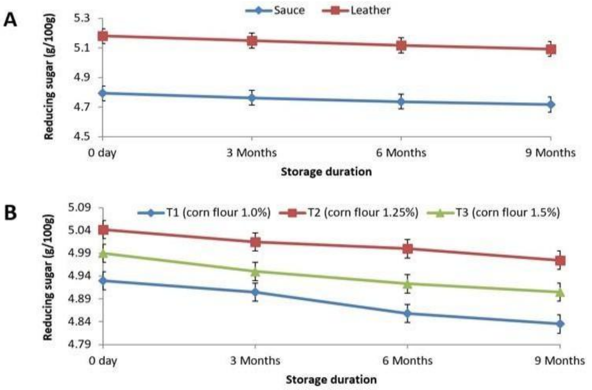

Figure 13. Effects of processed products, sauce and leather (A) and corn flour concentrations (B) on reducing sugar content of watermelon during storage. Vertical bars represent the standard error of mean.

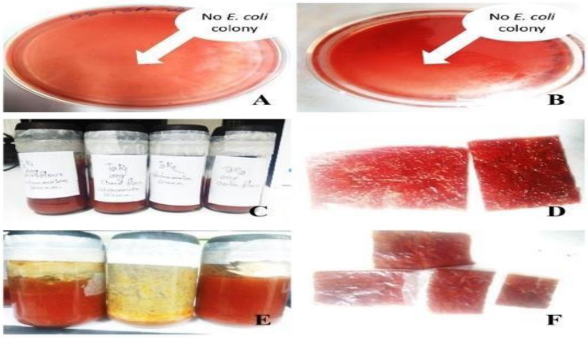

Figure 14. Watermelon sauce (A) and leather (B) after 9 months of storage without any *E. coli* colony on VRBA medium. Watermelon leather after 3 months of storage (C) and 9 months of storage (D) without any fungal growth. Watermelon sauce at the beginning of storage (E) and after 9 months of storage with visual fungal growth (F).

Microbial changes

After incubating watermelon leather and sauce suspensions on VRBA medium at room temperature for 4 days, no microbial colonies of *E. coli* were observed in fresh samples, as well as in samples stored for 3 months and 9 months (Fig. 14A and 14B). Additionally, no fungal growth was detected in the watermelon leather during the nine-month storage period (Fig. 14C and 14D). However, fungal growth was noted in the watermelon sauce after 9 months of storage (Fig. 14E and 14F). Concerning the corn flour concentration treatments, treatment T2 (corn flour 1.25%) exhibited the best performance, showing no colonies of *E. coli* and fungal growth. This outcome may be attributed to the neutral pH and high water activity, creating environments more favorable to yeasts and filamentous fungi. Watermelon sauce, with its higher water activity (wa) and nutrient content compared to fruit leather, provides a conducive environment for fungal spores to germinate and proliferate. Sugars and other organic components present in the sauce can serve as a food source for fungi, promoting their growth (Pitt & Hocking, 2009; Stratford et al., 2019).

Sensory evaluation

The watermelon leather obtained the highest scores on the hedonic scale for color, appearance, texture, stickiness, sweetness, flavor, and overall acceptability, while the sauce received the lowest scores (Table 2). Among the treatments, T2 (corn flour 1.25%) demonstrated the most favorable result, whereas the least favorable result was observed in T3 (corn flour 1.5%). The process of introducing new products involves conducting sensory studies that establish correlations between product formulation, storage conditions, processing parameters, and consumer responses. This approach furnishes valuable insights into the marketing potential of a product (Giacalone, 2018).

Table 2. The mean score for color, appearance, stickiness, sweetness, flavor and overall acceptability for various treatments and watermelon process products

Treatments and products	Color	Appearance	Stickiness	Sweetness	Flavor	Acceptability
T_1	4.82^c	4.27^c	4.40^b	4.50^b	4.77^b	4.80^c
T_2	5.75^a	5.72^a	5.07^a	5.42^a	5.67^a	5.52^a
T_3	4.25^b	4.35^b	4.27^c	4.32^c	4.15^c	4.82^b
Sauce	4.32^b	3.12^b	4.12^b	4.22^b	4.54^b	4.92^b
Leather	5.12^a	5.21^a	5.40^a	5.23^a	5.82^a	5.72^a
CV (%)	2.86	2.39	2.54	4.34	2.74	3.32
Level of significance	*	**	**	*	*	*

In the column, values having a similar letter (s) are statistically identical and those having the dissimilar letter (s) differ significantly at a 1% level of probability analyzed by DMRT. **= Significant at 1% level; *= Significant at 5% level. T1 = corn flour 1%; T2= corn flour 1.25% and T3= corn flour 1.50%. CV=coefficient of variation.

Conclusion

In conclusion, our study systematically examined the influence of different concentrations of corn flour on the development of watermelon processed products, namely sauce and leather. Over a nine-month storage period, key attributes such as weight loss, firmness, color, pH, and various nutritional components were monitored. Significant variations were observed among treatments, highlighting the crucial role of corn flour concentration in shaping the quality of watermelon processed products. Notably, watermelon leather, especially when treated with 1.25% corn flour, exhibited favorable results in terms of weight loss, firmness, color retention, and overall nutritional content compared to the sauce. This underscores the positive effects of 1.25% corn flour concentration on quality preservation. Microbial changes underscore the importance of formulation and storage conditions for product safety. Sensory evaluation affirmed the superiority of watermelon leather, suggesting its potential for consumer acceptance. In summary, our research provides valuable insights for the scientific community and the food industry, offering a comprehensive understanding of the effects of corn flour concentration on watermelon processed product development, quality, and storage stability. These findings can inform future product development, storage practices, and marketing strategies, contributing to innovation in the realm of fruit-based processed products.

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