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Research Article

Quality Evaluation and Storage Stability of Mixed Fruit Leather Prepared from Mango, Banana, and Papaya

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ABSTRACT

This study aimed to elucidate the formulation and quality evaluation of fruit leather prepared from Mango, Banana, and Papaya, and analyzes the shelf life of developed samples under different storage conditions. Three samples of fruit leather (F_1=50% mango pulp+20% banana pulp+19% papaya pulp, F_2= 70% mango pulp+10% banana pulp+9% papaya pulp, F_3=60% mango pulp+15% banana pulp+14% papaya pulp) were developed. The analysis of different compositions, such as moisture, ash, TSS (Total soluble solids), total sugar, acidity, crude fiber, and ascorbic acid of all fresh fruit pulps and developed fruit leathers were done. The moisture, ash, and total sugar contents of fruit leathers were in the range of 11.0–11.79%, 1.1–1.4%, and 54.1–55.4%, respectively. The fiber content ranged from 1.1% to 1.5%; sample F_2 contained the highest amount (1.5%). Vitamin C content was the highest in F_2 (17.5 mg/ 100 g), while F_3 gave the lowest (7 mg/100 g). The acidity of F_3 was the highest (0.21%), followed by F_2 (0.16%) and F_1 (0.12%). The sensory properties like color, texture, flavor, and overall acceptability of mixed fruit leather of sample F_2 (mango 70%, banana 10%, papaya 9%) was more acceptable than samples F_1 and F_3, which indicate mango-rich leathers were much better than Papaya and banana rich leathers. The mixed fruit leathers were packed in sealed low-density and high-density polyethylene and stored both at room temperature (25±1°C) and refrigerated temperature (4±1°C). The products were acceptable up to 4 months of storage and remained better in high-density polyethylene at room temperature than in other conditions.

Introduction

Mango (*Mangifera indica*) is a flowering plant that belongs to the class Magnoliopsida, the family Anacardiaceae, and the subfamily Anacardioideae. It is a commercially and nutritionally important tropical and subtropical tree fruit crop of the world (Mukherjee and Litz, 2009). Mangoes are grown in about 90 countries throughout the world, with Asia accounting for roughly 77 % of global mango output, while the Americas and Africa account for roughly 13 % and 9 %, respectively (Das et al., 2018). Bangladesh is the world's seventh largest mango grower (Dhaka Tribune, 2021). About 1165804 metric tons of mangoes were produced in Bangladesh in 2017-2018 on an area of 109584 acres (BBS, 2020). Due to its high palatability, superb taste, and flavor, it is known as the king of fruits (Kabir, et al., 2016). Mango pulp is also high in important minerals, vitamins, and other nutrients (Pawase et al., 2018). Raw mango must be processed into a range of products because it contains about 84% of water and has a short shelf life (Dang, et al., 2008).

Banana (*Musa sapientum*), a member of the Musaceae family, is grown in a variety of tropical and subtropical climates (Kapadia et al., 2015). Bangladesh is ranked 14th among the world's top 20 banana-producing countries (Hossain et al., 2016). During the 2017-2018 seasons, Bangladesh produced 810347 metric tons of bananas on 121384 acres of land (BBS, 2020). Bananas are low in fat and high in minerals like potassium, calcium, magnesium, and phosphorus (Mukul and Rahman, 2013; Youryon and Supapvanich, 2017.). Vitamin A, vitamin B, and ascorbic acid are also found in banana pulp (Emaga et al., 2008). Due to its perishable nature, it cannot be preserved for an extended amount of time (Mohiuddin et al., 2014; Newilah et al., 2009).

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The papaya (*Carica papaya)* is a tropical and subtropical fruit crop. It belongs to the Caricaceae family. Because of its scent, sweetness, and cream-like smoothness, papaya is quite popular. Vitamin C, vitamin A, vitamin B, vitamin K, and vitamin E are all abundant in papayas (Raja et al., 2017). According to the BBS (2020) data, papaya is grown on 38350 acres of land in Bangladesh, yielding 135809 metric tons in 2018-19. Papaya is widely cultivated in greater Rajshahi, Pabna, and Jessore (Kaysar et al., 2019), and is gaining popularity day by day due to its highly nutritious properties (Ara et al., 2016). However, the main issue is its post-harvest handling and marketing, which needs to be standardized through systematic experimentation.

Bangladesh's post-harvest losses of fresh fruits and vegetables are estimated to be between 25 and 50 percent of total production (Hossain et al., 2017). Ripe mango, banana, and papaya can only be kept in good condition for a few days after being picked (Sarmin et al., 2018). As a result, it is vital to use these fruits to make a variety of food products to extend their availability and maintain price stability during the off-season. Fruit leathers are a delightful and dehydrated product designed from fruit pulp that has greater nutritive benefits than fresh produce since all nutrients are consolidated and, as a result, would be a convenient food assortment to get the health advantages of fruits (Salleh et al., 2016). Although a substantial amount of information on the processing of mixed fruit leathers from various types of fruit pulp has been published (Amin et al., 2019; Vagadia et al., 2016; Salleh et al., 2016), research on the preparation of mixed fruit leathers from mango, banana, papaya varieties (Bangladeshi) is still very scanty. As a result, standardization and formulation of mixed fruit leather made of mango, banana, and papaya can help to improve the sensory features of the fruit bar while also saving money. Considering the above standpoints, the present study was performed (i) to develop the formulation of mixed fruit leather by using mango, banana, and papaya fruit pulp, (ii) to evaluate the effects of blend ratio on the chemical constituents of fruit bar and (iii) to assess storage stability of mixed fruit leather at different storage conditions.

Materials and Methods

This research work was performed in the laboratory of the Department of Food Technology and Rural Industries, Bangladesh Agricultural University, Mymensingh.

Ripe mango (variety name: Fazli), banana (variety name: shobree), and Papaya (Variety name: Shahi Papaya) were picked from the different markets of Mymensingh region. Other ingredients like sugar, starch, packaging materials, etc. were used from the stock of the departmental laboratory. AR (Analytical Research) grade solvents and chemicals were used for this study.

Preparation of mango pulp

Fresh ripe cleaned mangoes were peeled properly with a knife. The flesh was removed from the seed and cut into small uniform pieces and then blended perfectly. The mango pulp was then blanched (at 80°C for 10 minutes) and chilled quickly. Then the pulp was preserved at -20°C for future use.

Preparation of banana pulp

A fresh ripe washed banana was peeled. The flesh was taken out of the seed, cut into pieces, and then blended properly in an electrical blender. The pulp then went through a blanching operation (5 minutes at 80°C) and cooled. After that, the pulp was preserved at a temperature of -18°C for future application.

Preparation of papaya pulp

Fully ripe papayas were washed and peeled properly. Then the portion which is edible was separated from the non-edible one. The edible portions were cut down into small uniform slices. The crusher was used for crushing the slices. The pulp then went through a blanching operation like before (5 minutes at 80°C) and cooled. After that, the pulp was preserved at -18°C for future application.

Procedure for preparation of mixed fruit leathers

The basic formulation for the preparation of mixed fruit leathers

The basic formulation for mixed fruit leather is presented in Table 1.

Table 1. The basic formulation for the preparation of mixed fruit leather

Ingredient	Formulations %		
	F_1	F_2	F_3
Mango Pulp	50	70	60
Banana Pulp	20	10	15
Papaya Pulp	19	9	14
Sugar	10	10	10
Starch	1	1	1
Sodium benzoate	500 ppm	500 ppm	500 ppm

Preparation of mixed fruit leathers from mango, banana, and papaya pulp

At first mango pulp, banana pulp, and papaya pulp were taken and weighed properly by a balance. All formulations commonly contained 10% sugar, 1% starch, and 500 ppm sodium benzoate (Table 1). All the ingredients were blended entirely and heated at 80°C

for 5 minutes for starch gelatinization. Then the mixture was kept on a steel plate which was coated with a thin layer of polythene to impede the mixed bar from settling to the plate after the dehydration process. The mixture was then dried at a constant temperature of about 60°C for 18 hours. After that, the sheet was cut into (3"x1"x1/4") leather form. Then the mixed fruit leathers were packed in low-density polyethylene and high-density polyethylene and preserved at room temperature (25±1°C) and refrigeration temperature (4±1°C).

Quality Attributes Evaluation

The pulp of ripe mango, banana, papaya, and preserved leathers were examined for moisture content, ash content, total soluble solids (TSS), total sugar, fiber content, acidity, and vitamin C.

Proximate composition

AOAC methods had been applied to determine moisture content by using a hot air oven (AOAC, 2019b) and ash content using a muffle furnace (AOAC, 2019a).

Acidity

Rangana (1977) method had been followed to determine acidity.

Reducing sugar

Reducing sugar of samples was estimated using the method named Lane & Eynon (1923), as narrated by Asaduzzaman et al. (2020).

Non-reducing sugar

50 ml of purified solution had been taken in a conical flask. 5 gm of citric acid and 50 ml distilled water were mixed into it. Then the conical flask was heated for 10 minutes for addition of sucrose and finally cooled. The sample was then neutralized by 0.1 N NaOH solutions along with phenolphthalein as an indicator. The volume was made up to 100 ml with distilled water. After that titration of mixed Fehling's solution took place using similar procedure followed as that for reducing sugar. The percent invert sugar was then calculated by the similar procedure as for reducing sugar from which the percent non-reducing sugar is calculated as follows:

% Non-reducing sugar =% Invert sugar - %Reducing sugar

Estimation of total sugar

Total sugar was determined using the following formula:

% Total sugar = % Reducing sugar +% Non-reducing sugar.

Total soluble solids (TSS)

Two drops of ready pulp were kept in a refractometer (Model no. 8987 Puji Kuki Ltd. Tokyo, Japan) plate and the total soluble solids of the juice were obtained directly from the refractometer.

Vitamin-C content (Ascorbic acid)

Ascorbic acid was obtained following the method of Rangana (1977).

Determination of crude fiber

Crude fiber was determined according to the method elucidated in AOAC (2010).

Sensory Evaluation

Sensory properties like color, flavor, texture, and overall acceptability of prepared mixed leathers were evaluated by 10 semi-trained panelists on a 9-point hedonic rating scale (Amerine et al., 1965). The scale is Like extremely (9), Like very much (8), Like moderately (7), Like slightly (6), Neither like nor dislike (5), Dislike slightly (4), Dislike moderately (3), Dislike very much, and 1 = Dislike extremely.

Studies on the storage stability of mixed fruit leather

Packaging and storage

The mixed fruit leather samples were packed both in sealed low-density and high-density polythene bags. The samples were preserved at room (25±1°C) and refrigerated temperature (4±1°C). Low-density polythene permits easy passage of moisture and gasses in or out of the bag, while high-density polythene inhibits the passage of moisture and is a poor gas barrier. The water content of samples in the stated packaging systems was determined at a 1-month interval gravimetrically. First-order reaction kinetics (Heldman, 1975) was applied to analyze the effect of storage conditions on the moisture content of fruit leathers.

Quality parameters observed during storage

The color, flavor, and texture of mixed fruit leathers were observed at 15 days intervals during storage.

Statistical analysis

All experimental data obtained from minimum triplicate of samples and mean ± SD value was reported. Experimental data were obtained statistically by applying ANOVA (analysis of variance) and Fisher's LSD (least significant difference) methods to determine if there were any significant differences or not at a 5% level of significance using software named Stat View (Abacus Concepts Inc., Berkeley, CA, USA).

Results and Discussion

Chemical and nutritive characteristics of fresh mango, banana, and papaya

Moisture, ash, acidity, vitamin C, total soluble solids, protein, and sugar were measured in the mango, banana, and papaya pulp, and the findings are reported in Table 2. Mango pulp had moisture content, ash content, acidity, protein content, T.S.S., and total sugar of 81.6, 0.49, 0.16, 0.86, 16.2, and 15.2% respectively. Also, it contained 44 mg per 100g of vitamin C. The findings were similar to those of Pawase et al. (2018), who found that mango had a moisture content of 75 to 82 %, sugar content of 8.7 to 20%, protein content of 0.51 %, citric acid content of 0.14 to 0.71, vitamin C content of 8.5 to 50 mg per 100 g, and ash content of 0.38 to 0.63 %. Banana pulp contained moisture content, ash, acidity, total soluble solids, and total sugar of 85.56, 0.361, 0.73, 12.7, and 10.41 % respectively. In addition, it had 4.38 mg/100 g of vitamin C. Patel et al. (2017) discovered that the banana had a moisture content of 85-90 %, vitamin C of 4.3 mg/100 g, ash of 0.361 %, acidity of 1.04 %, pH of 2.57, TSS of 14.38 %, total sugar of 13.42 %. According to Table 2, papaya pulp contained 88% moisture, 0.287 % ash, 10% TSS, 29.2 mg/100 g vitamin C, 0.09 % acidity, and 8.3 % total sugar. The composition and dietary value of papaya fruit are: moisture 89.6%, protein 0.5 percent, carbohydrate 10%, fat 0.1 percent, calcium 0.01 percent, phosphorus 0.01 percent, iron 0.4 mg/100 mg, and vitamin C 40 mg/100gm, according to Patel et al. (2017).

Table 2. Chemical and nutritive characteristics of fresh mango, banana, and papaya pulp

Parameter	Mango	Banana	Papaya
Moisture (%)	81.6±0.18^a	85.56±0.12^b	88±0.08^c
Vitamin C (mg/100 g)	44±0.03^a	4.38±0.01^b	29.2±0.06^c
Ash (%)	0.49±0.12^c	0.361±0.08^b	0.287±0.11^a
Total soluble solids (TSS, %)	16.2±0.01^c	12.7±0.04^a	10±0.01^b
Acidity (%)	0.16±0.06^a	0.79±0.08^b	0.09±0.01^c
Total sugar (%)	15.2±0.11^a	10.41±0.12^b	8.3±0.18^c

Note: Mean ± SD, for each analysis, the mean is the average of three replicates. Within the same raw, values with the same superscript indicate no significant difference at P<0.05.

Nutritional and chemical characteristics of mixed fruit leather

The compositions of mixed fruit leather samples are shown in Table 3. Varied samples treated with different quantities of fruit pulps had moisture, ash, and total sugar content ranging from 10.99 to 11.69 %, 1.13-1.36 %, and 54.08-55.38 %, respectively. It also shows that fiber content ranged from 1.13 to 1.5 percent, with F_2 having the most (1.50 %). F_2 had the highest vitamin C content (17.49 mg/100 mg), while F_3 had the lowest (7 mg/100g). F_3 had the highest acidity (0.21 %), followed by F_2 (0.16 %), and F_1 (0.12 %). Asaduzzaman et al. (2020) reported that the compositions of mixed fruit leather samples were almost identical. However, samples F_1 and F_3 were in the same group (P>0.05), differing from F_2 based on ash content. Furthermore, there was no statistically significant difference (P>0.05) between F_1 and F_2 in terms of acidity or F_2 and F_3 in terms of total sugar.

Table 3. Nutritional and chemical characteristics of mixed fruit leather from mango pulp, banana pulp, papaya pulp

Parameter	Formulation		
	F_I	F_2	F_3
Moisture (%)	10.99±0.01^a	11.69±0.13^b	11.49±0.25^c
Vitamin C (mg/100 g)	10.2±0.19^c	17.49±0.17^b	7.00±0.15^a
Ash (%)	1.13±0.02^a	1.36±0.03^b	1.13±0.01^a
Acidity (%)	0.12±0.01^a	0.16±0.02^a	0.21±0.01^b
Total sugar (%)	54.08±0.05^a	55.13±0.14^b	55.38±0.22^b
Fiber (%)	1.13 ± 0.03^c	1.50 ± 0.02^b	1.35 ± 0.06^a

Note: Mean ± SD, for each analysis, the mean is the average of three replicates. Within the same raw, values with the same superscript indicate no significant difference at P<0.05. Sample F_1= 50% mango pulp +20% banana pulp+ 19% papaya pulp, Sample F_2= 70% mango pulp +10% banana pulp+ 9% papaya pulp, Sample F_3= 60% mango pulp +15% banana pulp+ 14% papaya pulp.

Sensory analysis

The color, flavor, texture, and overall acceptability of fruit bars produced from mango, banana, and papaya pulp were evaluated by a panel of ten judges. Table 4 shows the mean scores for color, flavor, texture, and overall acceptability of mixed fruit leathers, F_1, F_2, and F_3. For color preference, a two-way analysis of variance (ANOVA) was used, and the findings revealed a significant (P<0.05) difference in color acceptance among the fruit leathers. F_2 received the highest score (8.3), while F_3 and F_1 received 5.9 and 6.6, respectively. ANOVA analysis revealed a significant (p<0.05)

difference in flavor preference across the fruit leathers, with F_2 receiving the highest score (7.9%), followed by F_1 and F_3. There was also a significant ($p<0.05$) difference in texture, with F_2 receiving the highest score (7.8) and F_3 receiving the lowest (6.2.). Because the estimated F value (15.1688) was larger than the tabulated F value, it was clear from the ANOVA findings that there was a significant ($p<0.05$) difference in the overall acceptability of the samples (6.2). It implies that the mixed leathers' overall acceptability was not equal, with F_2 receiving the highest score (8.3) among the others. So, considering all, F_2 (70% mango pulp, 10% banana pulp, and 9% papaya pulp) is regarded as the best product.

Table 4. Mean score for color, flavor, texture, and overall acceptability of mixed fruit bars

Sample code	Sensory attribute			
	Color	Flavor	Texture	Overall Acceptability
F_1	6.6±0.01[a]	6.4±0.13[a]	7.2±0.05[a]	7.0±0.06[a]
F_2	8.3±0.02[b]	7.9±0.01[b]	7.8±0.01[b]	8.3±0.02[b]
F_3	5.9±0.11[c]	7.2±0.09[c]	6.2±0.01[c]	7.6±0.01[c]

Note: Mean ± SD, for each analysis, the mean is the average of three replicates. Within the same column, values with the same superscript indicate no significant difference at $P<0.05$. Sample F_1= 50% mango pulp +20% banana pulp+ 19% papaya pulp, Sample F_2= 70% mango pulp +10% banana pulp+ 9% papaya pulp, Sample F_3= 60% mango pulp +15% banana pulp+ 14% papaya pulp.

Storage studies of mixed fruit leather

The quality factors affecting the shelf life of mixed fruit leathers are storage conditions, moisture content, fungal growth, etc. Moisture absorption or desorption of the product's during storage was determined, and leathers were visually organoleptically examined for quality parameters like color, flavor, texture, and fungal growth under different storage conditions. Moreover, composition analysis of mixed fruit leather was carried out under different storage conditions for up to 5 months.

Effect of storage conditions on the moisture content of mixed fruit leather

Moisture absorption and moisture removal are the two key characteristics that must be evaluated for all sorts of dried and high-sugar products in terms of determining their shelf life. Accordingly, developed products were preserved at room temperature (RT, 25±1°C) and refrigerated temperature (RFT, 4±1°C) for periods up to 20 weeks. The products were packed in either high-density polyethylene (HDP) or low-density polyethylene (LDP). Utilizing first-order reaction kinetics (Heldman, 1975 & Amin et al., 2019) by plotting moisture ratio as a function of time on the semi-log coordinate (Figures 1, 2, and 3), regression equations had been established (Table 5).

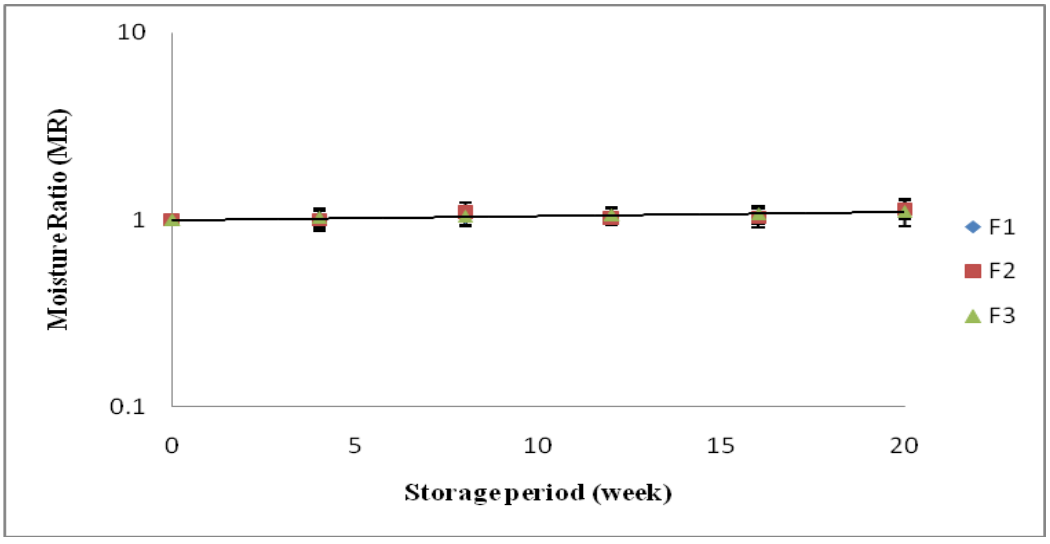

Figure 1. Moisture ratio of mixed fruit leather in high-density polythene (HDP) at room temperature (25±1 °C) as a function of storage period.

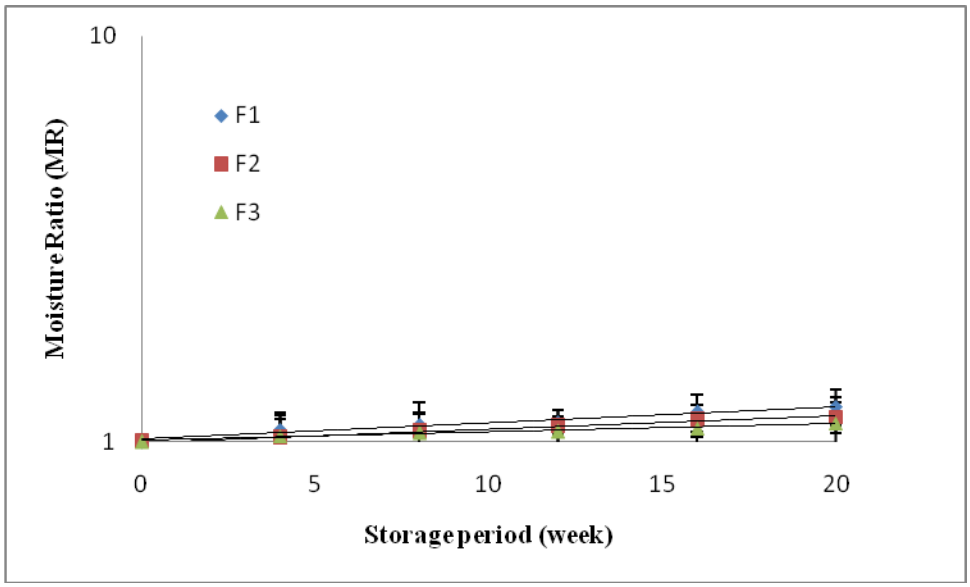

Figure 2. Moisture ratio of mixed fruit leather in low-density polythene (LDP) at room temperature (25±1°C) as a function of storage period.

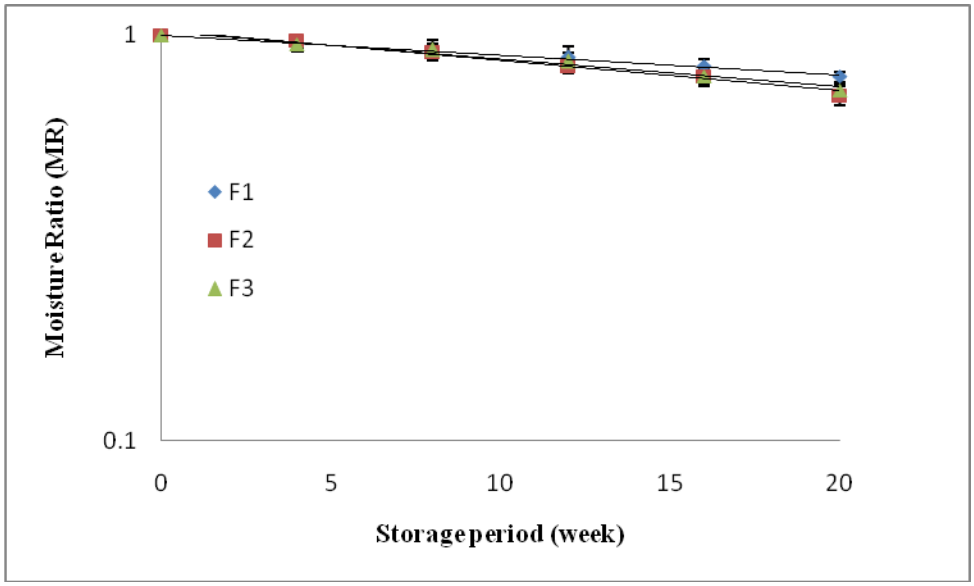

Figure 3. Moisture ratio of mixed fruit leather in low-density polythene (LDP) at refrigerated temperature (4±1°C) as a function of the storage period

From Tables (5 and 6) as well as figures (1, 2, and 3), it is seen that at RT (25±1°C) all these products (F_1, F_2, and F_3) in high-density polyethylene **(**HDP) gave the same rate constant (0.004 per week), while products in low-density polyethylene **(**LDP) gave higher rate constant value (0.005 to 0.009 per week), indicating that HDP gave higher resistance to mass transfer compared to LDP. Again, it is seen that all products in LDP at RFT (4±1°C) gave a similar rate constant (0.01per week) having a negative value indicating desorption or dehydration (Tables 5 and 6). Singh et al., (2013) also found similar results. This means that under refrigerated conditions packaged products gave up moisture and got dehydrated. This might be due to the temperature difference between the product and refrigerator wall as well as the water activity gradient between the product and cold air (Singh et al., 2013; Severns and Fellows, 1958).

Table 5. Effect of storage conditions on the moisture content of mixed fruit leather

Sample	HDP (RT)	LDP (RT)	LDP (RFT)
F_1	$MR=0.993e^{0.004t}$	$MR=1.013e^{0.009t}$	$MR=0.999e^{-0.01t}$
F_2	$MR=0.995e^{0.004t}$	$MR=0.997e^{0.007t}$	$MR=1.026e^{-0.01t}$
F_3	$MR=1.004e^{0.004t}$	$MR=1.004e^{0.005t}$	$MR=1.017e^{-0.01t}$

MR=Moisture Ratio, t= week^{-1}. HDP= High-density polyethylene, LDP= Low-density polyethylene, RT= Room temperature (25±1°C), RFT= Refrigerated temperature (4±1°C)

Table 6. The values of the rate constant (per week) at different storage conditions

	Rate constant (per week)		
Formulations	High-density polyethylene (RT)	Low-density polyethylene (RT)	Low-density polyethylene (RFT)
F_1	0.004	0.009	-0.01
F_2	0.004	0.007	-0.01
F_3	0.004	0.005	-0.01

RT= Room temperature (25±1°C), RFT= Refrigerated temperature (4±1°C)

Visual and organoleptic examination of quality parameters of mixed fruit leathers at different storage conditions

The color, flavor, and texture of mixed fruit leathers were observed visually organoleptically at 15 days intervals up to 60 days and then 30 days intervals till 120 days. The observations are presented in Table 7 for samples in high-density polyethylene **(**HDP) at RT and RFT, and Table 8 for samples in LDP at RT and RFT. From Table 7 it is seen that the quality parameters such as color, flavor and texture in the storage period at room temperature were good for 4 months. The texture got slightly hard at 4±1°C (RFT) after 90 days of storage period. However, no off-flavor was produced for both room temperature and refrigerated temperature. Table 8 shows that after 90 days, the texture became hard due to the removal of moisture in refrigerated conditions and had been softer than before at room temperature. But the flavor was unchanged.

Table 7. Sensory properties of mixed fruit leather with high-density polyethylene (HDP) at 25±1°C (RT) and 4±1°C (RFT)

Storage period (days)	Samples	Color		Flavor		Texture		Fungal Growth		Remarks	
		RT	RFT	RT	RFT	RT	RFT	RT	RFT	RT	RFT
0	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
15	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
30	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
45	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
60	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
90	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
120	F_1	DB	DB	P	P	S	SH	NV	NV	A	A
	F_2	B	B	P	P	S	SH	NV	NV		
	F_3	B	B	P	P	S	SH	NV	NV		

DB=Deep brown, B=Brown, P=Pleasant, S=Soft, SH=Slightly hard, NV=Not Visible, A= Acceptable

Table 8. Sensory properties of mixed fruit leather with low-density polyethylene (LDP) at 25±1°C (RT) and 4±1°C (RFT)

Storage period (days)	Samples	Color		Flavor		Texture		Fungal Growth		Remarks	
		RT	RFT	RT	RFT	RT	RFT	RT	RFT	RT	RFT
0	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
15	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
30	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
45	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
60	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
90	F_1	DB	DB	P	P	S	S	NV	NV	A	A
	F_2	B	B	P	P	S	S	NV	NV		
	F_3	B	B	P	P	S	S	NV	NV		
120	F_1	DB	DB	P	P	SS	H	NV	NV	A	A
	F_2	B	B	P	P	SS	H	NV	NV		
	F_3	B	B	P	P	SS	SH	NV	NV		

DB=Deep brown, B=Brown, P=Pleasant, S=Soft, SS= Slightly soft than before, SH=Slightly hard, H= Hard, NV=Not Visible, A= Acceptable

Composition analysis of mixed fruit leather at different storage conditions

Figure 4 reveals that moisture content and TSS increased every month when stored in high-density polyethylene (HDP) at room temperature (25±1°C). However, acidity and ascorbic acid decreased day by day because of some factors such as temperature, light, time, and oxygen (Kittur et al., 2001). However, with low-density polyethylene (LDP) stored at storage temperature (4±1°C), moisture content and TSS decreased day by day. The observed differences in moisture content increase or decrease with time depending on the type of packaging, i.e., HDP and LDP, as well as the vapor pressure gradient between the sample and the surrounding atmosphere (Heldman, 1975; Alam and Islam, 2014). Overall, mixed fruit leathers were suitable for storage periods up to 4 months, and products remained better in high-density polyethylene than in low-density polyethylene.

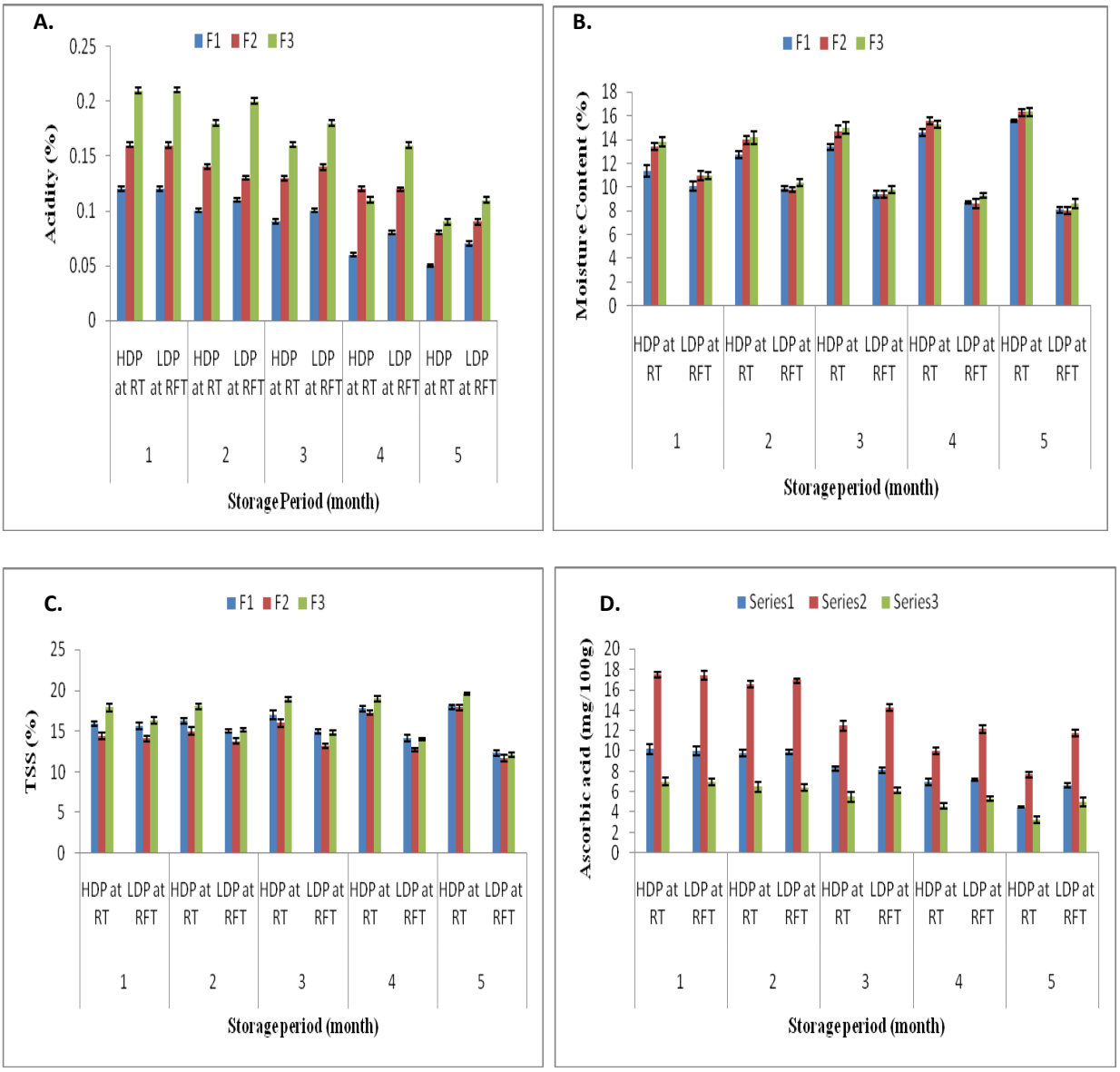

Figure 4. Composition analysis of mixed fruit leather at different storage conditions: A. Acidity; B. Moisture; C. TSS; D. Ascorbic acid contents

Conclusion

This study elucidates the formulation of mixed fruit leather from Mango, Banana, and Papaya and shelf-life studied of developed samples under different storage conditions. Every year, a large proportion of mango, banana, and papaya deteriorate in Bangladesh. Insufficient and improper knowledge on the processing and preservation of many important and popular fruits such as mango, banana, and papaya are the reasons for increasing post-harvest losses of these commodities. Processing of fruit leather from these widely grown highly perishable fruits can be a great resolution to cut down post-harvest losses of these commodities.

References

Alam, M.M. and Islam, M.N. 2014. Study on Drying Kinetics of Summer Onion. *Bangladesh Journal of Agricultural Research*, 39(4): 661–673. https://doi.org/10.3329/bjar.v39i4.22545

Amerine, M.A., Pangborn, R.M. and Roessler, E.B. 1965. Principles of sensory evaluation of food. *Academic Press*. 1–27. https://doi.org/10.1016/B978-1-4832-0018-7.50005-2

Amin, M.K., Islam, M.A., Akter, F. and Islam, M.N. 2019. Kinetics of air drying of jackfruit and mango pulp and development of mixed leather. *Fundamental and Applied Agriculture* 4(4): 1089–1096. https://doi.org/10.5455/faa.72409

AOAC International. 2019a. Official Method 920.153 Ash in Meat and Meat Products (21st ed.).

AOAC International. 2019b. Official Method 950.46. Moisture in Meat and Meat Products (21st ed.).

AOAC. 2010. Official Methods of Analysis of Association of Official Analytical Chemists. 18th Edition, Washington, DC.

Ara, N., Moniruzzaman, M., Begum, F., Moniruzzaman, M. and Khatoon, R. 2016. Genetic divergence analysis in papaya (Carica papaya L.) Genotypes. *Bangladesh Journal of Agricultural Research*, *41*(4): 647–656. https://doi.org/10.3329/bjar.v41i4.30697

Asaduzzaman, M., Hasan, N. and Begum, K. 2020. Comparisons of proximate composition, sensory evolution, and bioactive compounds of mixed fruit bar from mango, pineapple, and papaya. *International Journal of Scientific & Engineering Research*, 11 (10).

BBS (Bangladesh Bureau of Statistics). (2020). Area and Production of (winter) Vegetable by crops. Statistical yearbook of Bangladesh, Statistics, and Informatics Division. Ministry of planning, Govt. of the Peoples Republic of Bangladesh, Dhaka. 341–356.

Das, P.C., Sattar, S., Jony, M.E. and Islam, M.N. 2018. Rehydration kinetics of flour from dehydrated mango kernel. *Food Research*, 2 (5): 474–480. https://doi.org/10.26656/fr.2017.2(5).210

Dang, K.T.H., Singh, Z. and Swinny, E.E. 2008. Edible coatings influence fruit ripening, quality, and aroma biosynthesis in mango fruit. *Journal of Agricultural and Food Chemistry*, 56: 1361–1370. https:// doi.org/10.1021/jf072208a

Dhaka Tribune. 2021. Bangladesh 7th largest mango producer in the world, The Dhaka Tribune, July 18th, 2021.

Emaga, T.H., Andrianaivo, R.H., Wathelet, B., Tchango, J.T. and Paquot, M. 2008. Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. *Food Chemistry*, 103: 590–600. https://doi.org/10.1016/j.foodchem.2006.09.006

Heldmn, D.R. 1975. Food Process Engineering. 2nd edition, Westport, Connecticut, The avi publishing company, Inc.

Hossain, M.M., Abdulla, F. and Majumder, A.K. 2016. Forecasting of Banana Production in Bangladesh. *American Journal of Agricultural and Biological Sciences 2*, 11 (2): 93.99. https://doi.org/10.3844/ajabssp.2016.93.99

Hossain, M.A., Khatun, M., Matin, M.A. and Dewan, M.F. 2017. Postharvest Loss Assessment of Major Fruits Grown in hill Regions of Bangladesh. *Bangladesh Journal of Agricultural Research,* 42(1): 2408–8293. https://doi.org/10.3329/bjar.v42i1.31989

Kabir, S., Alam, A. and Uddin, B. 2016. Antioxidant Content of Selected Mango Varieties and Their Correlation with the Shelf-Life of Developed Products. *IRA-International Journal of Applied Sciences*, 4(2): 237. http://dx.doi.org/10.21013/jas.v4.n2.p4

Kapadia, S.P., Pudakalkatti, P.S. and Shivanaikar, S. 2015. Detection of antimicrobial activity of banana peel (*Musa paradisiaca* L.) on Porphyromonas gingivalis and Aggregatibacter actinomycetemcomitans: An in vitro study. *Contemporary Clinical Dentistry*, 6(4): 496–499. https://doi.org/10.4103/0976-237X.169864

Kaysar, M., Hoq, M. and Islam, M. 2019. Profitability analysis of papaya cultivation in some selected areas of Bangladesh. *Bangladesh Journal of Agricultural Research,* 44(1): 115–126. https://doi.org/10.3329/bjar.v44i1.40936

Kittur, F.S., Saroja, N. and Tharanathan, H.R.N. 2001. Polysaccharide-based composite coating formulations for shelf-life extension of fresh banana and mango. *European Food Research and Technology*, 213(4–5): 306–311. https:// doi.org/10.1007/s002170100363

Lane, J.H. and Eynon, L. 1923. Determination of reducing sugars by means of Fehling's solution with methylene blue as internal indicator. *Journal of the Society of Chemical Industry,* 42: 32–36.

Mohiuddin, A.K.M., Saha, M.K., Hossian, M.S. and Ferdoushi, A. 2014. Usefulness of banana (Musa paradisiaca) wastes in manufacturing of bioproducts: A review. *Agriculture*, 12: 148–158. https://doi.org/10.3329/agric.v12i1.19870

Mukherjee, S.K. and Litz, R.E. 2009. Introduction: botany and importance, in The Mango; Botany, Production and Uses 2nd Ed, ed Litz R. E. (Wallingford, CT; Oxen: CAB International;), 1–18. https://doi.org/10.1079/9781845934897.0001

Mukul, A.Z.A. and Rahman, M.A. 2013. Production and profitability of banana in Bangladesh-an economic analysis, 1: 159–165. https://doi.org/ 10.11648/j.ijefm.20130103.15

Newilah, G.N., Tomekpe, K., Fokou, E. and Etoa, F.X. 2009. Physicochemical Changes during Ripening of Bananas Grown in Cameroon. *Fresh Produce*, 3 (1): 64–70. https://doi.org/10.1051/fruits/2009015

Pawase, P.A., Gaikwad, M.P. and Kukade A.G. 2018. Standardization and formulation of fig mango mix fruit bar. *International Journal of Chemical Study*, 6(6): 394–398. https://www.researchgate.net/publication/348541252

Patel, M., Ravani, A. and Joshi, D.C., 2017. Optimization of Level of Ingredients for Production of Banana Papaya Mixed Fruit Bar Using Response Surface Methodology. *International Journal of Agriculture, Environment and Biotechnology*, 10(3): 321–326. https://doi.org/10.5958/2230-732X.2017.00049.3

Raja, K. S., Taip, F.S., Azmi, M.M.Z. and Shishir, M.R.I. 2017. Effect of pre-treatment and different drying methods on the physicochemical properties of *Carica papaya* L. leaf powder. *Journal of the Saudi Society of Agricultural Sciences*. https://doi.org/10.1016/j.jssas.2017.04.001

Ranganna, S. 1977. Handbook of analysis and quality control for fruit and vegetable products, 2nd edition. Pun. Tata Mcgraw Hill publishing company limited, New Delhi.

Salleh, R.H., Ying, T.L. and Mousavi, L. 2016. Development of fruit bar using Sapodilla (Manilkara Zapota L.). *Journal of Food Processing and Preservation*, 41(2): 1–7. https://doi.org/10.1111/jfpp.12806

Sarmin, R.A., Khan, S.A.K.U., Fatema, K. and Sultana, S. 2018. Effect of neem leaf and banana pulp extracts on shelf life and quality of mango (Mangifera indica L.). *Journal of Bangladesh Agricultural University,* 16(3): 343–350. https:// doi.org/10.3329/jbau.v16i3.39488

Severns, W.H. and Fellows, J.R. 1958. Air Conditioning & Refrigeration. 1st edition, John Wiley & Sons.

Singh, S., Kulkarni, S.D. and Shridevi, K.S. 2013. Quality of mango bar stored in three types of packaging material. *Journal of Food Science and Technol*ogy, 40(1): 84–88.

Vagadia, P., Senapati, A., Tank, R., Mayani, J. and Koyani, B. 2016. Evaluation of Physico-Chemical and Organoleptic Quality of Papaya Cv. Taiwan and Banana Cv. Grand Naine Based Mixed Fruit Bar During Storage. *International Journal of Agriculture, Environment and Biotechnology*. https://doi.org/10.5958/2230-732X.2016.00071.1

Youryon, P. and Supapvanich, S. 2017. Physicochemical quality and antioxidant changes in 'Leb Mue Nang' banana fruit during ripening. *Agriculture and Natural Resources*, 51(1): 47–52. https://doi.org/10.1016/j.anres.2015.12.004