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Storage quality evaluation of low-sugar bread spreads prepared from papaya and pineapple

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Abstract
The current investigation was carried out at the Division of Postharvest Technology & Agricultural Engineering, ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru, during the period of 2024-25. For papaya-based spreads, the treatments included T_1 (Control), T_2 (80% papaya pulp + 20% sugar), and T_3 (80% papaya pulp + 20% honey). Similarly, pineapple-based formulations comprised T_4 (Control), T_5 (80% pineapple pulp + 20% sugar), and T_6 (80% pineapple pulp + 20% honey). All samples were stored for three months and periodically assessed for key physicochemical attributes, including Total Soluble Solids (TSS), titratable acidity, ascorbic acid and carotenoid content, along with sensory quality parameters. Carotenoid content values ranged from 4.428 to 7.775 mg/100g at initial in papaya- based Jam and 0.817 to 1.124 mg/100g in pineapple-based jam. After three months, these values decreased to 3.710 - 6.875 mg/100g in papaya-based spread and 0.723 - 1.023 mg/100g in pineapple-based spreads. Similarly, in papaya-based treatments ascorbic acid level decreased from 95.00-105.00 mg/100g initially to 75.92 -79.81 mg/100g after three months and also pineapple jam showed a reduction from 69.32 -70.38 mg/100g at the initial stage to 50.97 - 52.79 mg/100g by the end of storage. A Completely Randomized Design (CRD) was adopted to formulate and evaluate six treatments. The findings revealed that both sugar and honey-based bread spreads maintained desirable physico-chemical and sensory qualities throughout the storage period. Among the treatments, spreads containing 20% sugar or 20% honey recorded better acceptability and stability compared to controls. The study confirms that nutritious, low-sugar bread spreads can be successfully made from papaya and pineapple using sugar or honey, offering a healthier alternative to conventional high-sugar spreads.

Keywords: Papaya, pineapple, osmotic treatment, physico-chemical parameters, fruit spread (jam), sensory evaluation

Introduction
Fruit jam is one of the most widely consumed processed fruit products globally, valued for its affordability, year-round availability and appealing sensory attributes. Classified as an intermediate-moisture food, jam is typically produced by boiling fruit pulp with sucrose, pectin, acid, and optional additives such as preservatives, flavoring agents and colorants. The mixture is cooked to achieve a thick consistency capable of retaining suspended fruit tissues. As per the Food Safety and Standards Authority of India (FSSAI), jam must contain not less than 65% total soluble solids (TSS) and a minimum of 45% fruit content.
Conventional jam is considered a high-calorie product primarily due to its elevated sucrose content. Excessive intake of refined sugar has been linked to major health issues such as obesity, diabetes and cardiovascular diseases. Growing awareness of healthy dietary practices has led to increased consumer demand for low-calorie and nutritionally enhanced alternatives. Consequently, the health food industry is actively exploring strategies to reduce sucrose levels in processed foods. One such approach involves partially or fully replacing sucrose with carbohydrate-based or non-carbohydrate sweeteners, while maintaining acceptable taste, texture and overall quality.
The demand for reduced-calorie jams has encouraged efforts to lower sucrose content and increase the proportion of fruit in formulations to improve both nutritional value and consumer satisfaction. In addition to reformulation strategies, alternative methods of jam preparation have also been explored. The use of dehydrated fruits has been reported to reduce the need for prolonged cooking and concentration during processing, resulting in

products with higher fruit content, lower sugar dependency and improved flavor and nutritional retention (Shi *et al.*, 1996) [17]. Osmotic dehydration, in particular, has been shown to minimize losses of vitamins and minerals while enhancing aroma and overall organoleptic quality.

Papaya (*Carica papaya* L.) is an important tropical fruit cultivated extensively in India and other tropical and subtropical regions. In India papaya is mainly cultivated in Uttar Pradesh, Bihar, Assam, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Maharashtra, West Bengal, Orissa, Manipur and Meghalaya. It is rich in carbohydrates, vitamin A, calcium, iron, phosphorus, fiber, magnesium, lipids and essential amino acids. The fruit typically has a total soluble solids (TSS) content of 13 - 15°Brix. A unique characteristic of papaya is the presence of papain, a proteolytic enzyme that aids protein digestion. Despite its nutritional value, papaya is highly perishable due to its high post-harvest metabolic activity. This leads to glut during peak seasons, market price reduction and substantial post-harvest losses, necessitating the development of preservation techniques to extend shelf life and ensure off-season availability (Damanpreet Kaur *et al*., 2024) [10].

Pineapple (*Ananas comosus* L.) is another commercially important tropical fruit known for its characteristic flavor and rich nutritional profile. In India pineapple is grown in Karnataka, Meghalaya, West Bengal, Kerela, Assam, Manipur, Tripura, Arunachal Pradesh, Mizoram, and Nagaland. It is a significant source of carotene and vitamin C (ascorbic acid), along with appreciable levels of vitamins B and B_2. The TSS of pineapple ranges from 12 to 16°Brix. The fruit also provides essential minerals such as phosphorus, calcium, magnesium, potassium and iron. Pineapple contains bromelain, a proteolytic enzyme associated with digestive and therapeutic benefits.

Honey has emerged as a potential natural sweetening alternative in fruit-based products. It is primarily composed of fructose (≈38.2%) and glucose (≈31%), with minor sugars such as sucrose, maltose, isomaltose, maltulose, turanose and kojibiose contributing approximately 9%. Its high Brix value of 77.5° reflects its inherent sweetness. Honey possesses a lower glycaemic index compared to refined sugar, indicating a slower effect on blood glucose levels. Additionally, it offers digestive and immune-supportive properties and has been reported to inhibit enzymatic browning and enhance sensory quality in food products (Osmanski & Lee, 1990) [12]. Given the increasing demand for healthier fruit spreads, the present investigation aimed to develop papaya and pineapple jam using both refined sugar and honey as sweeteners, with a focus on improving nutritional quality while retaining consumer acceptability.

Material and methods

Materials

Procurement of Raw material

The research was carried out in the Product development Laboratory at Indian Institute of Horticulture, Hessaraghatta, Bengaluru. Pineapple variety 'Queen', Papaya variety 'Red Lady,' were procured from the local market of Bengaluru. Fully-ripened, undamaged fruits, free from bruises were carefully selected to ensure optimal quality for jam preparation.

Preparation of osmosed pulp

Fresh papaya and pineapple fruits were thoroughly washed, peeled, and sliced uniformly. It was subjected to osmotic dehydration in 60ºBrix sugar syrup (with other additives) in the 1:2 fruit to syrup ratio. The slices were immersed overnight to promote water loss and solute infusion. Thereafter, osmosed slices were removed from the syrup and blended into a smooth, homogeneous pulp, which served as a concentrated base for jam preparation using standardized formulation techniques to ensure optimal consistency, flavor and storage stability.

Preparation of low sugar bread spread

The osmosed papaya or pineapple pulp was heated until the total soluble solids (TSS) reached 45-50°Brix, followed by the addition of required quantity of sugar or honey with continuous stirring. Citric acid was then incorporated, and the mixture was boiled until the TSS reached around 68°Brix. After achieving the desired consistency, the jam was hot-filled into pre-sterilized containers, sealed immediately, cooled at room temperature and stored under ambient conditions for further storage quality evaluation.

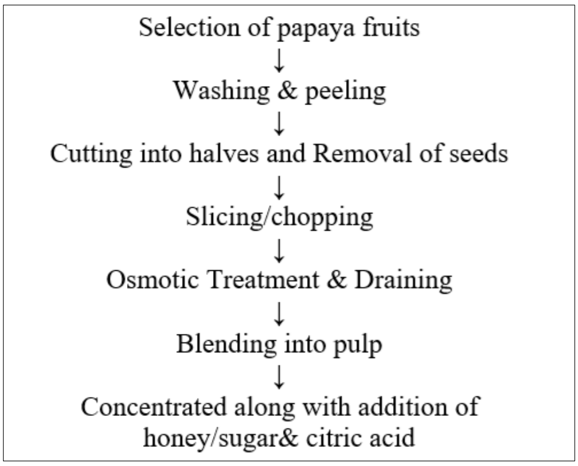

Fig 1: Flow chart for preparation of papaya low sugar bread spread

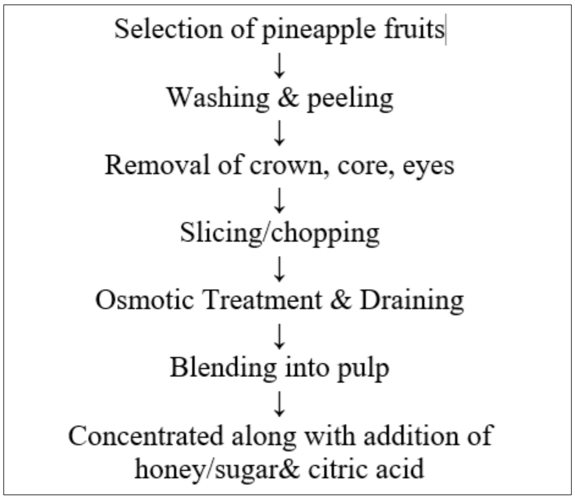

Fig 2: Flow chart for preparation of pineapple low sugar bread spread

Treatment details

T_1: Control-Papaya low sugar bread spread
T_2: Papaya pulp (80%) + Sugar (20%)
T_3: Papaya pulp (80%) + Honey (20%)
T_4: Control -Pineapple low sugar bread spread
T_5: Pineapple pulp (80%) + sugar 20%)
T_6: Pineapple pulp (80%) +Honey (20%)

Physico - chemical Analysis

The total soluble solids (TSS) of papaya and pineapple low sugar bread spread were measured using Atago digital handheld refractometer (0-93 °Brix) with appropriate temperature corrections, ensuring proper cleaning before each reading. Titratable acidity was determined by the AOAC (942.15) method, in which 5 ml aliquot was titrated against 0.1 N NaOH using phenolphthalein as an indicator, with results expressed as per cent citric acid.

Ascorbic acid content was estimated by the 2,6-dichlorophenol indophenol titration method (Ranganna, 1991) [14] using 10 g of sample blended with 3% metaphosphoric acid, volume made up to 100 ml, filtered and a 10 ml aliquot titrated with the dye solution; results were expressed as mg ascorbic acid per 100 g of sample.

Total carotenoids were determined spectrophotometrically (UV-Visible Spectrophotometer, Model T70, PG Instruments Ltd.) by extracting 1 g of sample with acetone followed by partitioning into petroleum ether, washing with distilled water, and drying with anhydrous sodium sulphate. The optical density was recorded at 452 nm and the carotenoid content was calculated using a standard β-carotene curve (Ranganna, 1991) [14].

Results and discussion

Physico-chemical Composition of bread spread

Data related to physico - chemical parameters which include total soluble solids, titratable acidity, ascorbic acid content, carotenoids were presented below

Total Soluble Solids (TSS)

Data presented in Table 1 indicate that the Total Soluble Solids (TSS) content of low-sugar papaya and pineapple bread spreads was in the range of 69.12 to 70.16ºB in papaya and 69.86 To 70.10 ºB in pineapple jam which was statistically at par across all treatments at initial and during storage period. However, there was minor increase in TSS during advancement of storage period.

Table 1: Effect of addition of sugar and honey on the TSS content of papaya and pineapple bread spread during storage

Treatment details	Treatment code	TSS(°B)			
		Initial	1 MAS	2 MAS	3 MAS
Control -Papaya bread spread	T_1	68.69	68.92	69.20	69.41
Papaya (80%) + Sugar (20%)	T_2	69.12	69.57	69.80	70.16
Papaya (80%) + Honey (20%)	T_3	68.51	68.74	69.34	69.76
Control-Pineapple bread spread	T_4	68.10	68.32	68.64	69.10
Pineapple (80%) + Sugar (20%)	T_5	69.86	69.88	69.96	70.10
Pineapple (80%) + Honey (20%)	T_6	68.25	68.48	68.93	69.12
S.Em ±		3.97	3.33	4.00	3.82
CD at 5%		NS	NS	NS	NS

Titratable acidity (%)

Data given in Table 2 indicates that there was significant differences about titratable acidity content among all the treatments at initial and also during entire period of storage.

Titratable acidity in papaya-based bread spreads initially ranged from 0.660% to 1.070%, which increased to 0.732% to 1.200% after three months of storage. Similarly, pineapple-based spreads showed acidity values ranging from 0.692% to 1.040% at the initial stage, rising to 0.751% to 1.110% by the end of the storage period. Overall, all treatments exhibited a progressive increase in titratable acidity throughout the three-month storage duration. This upward trend is attributed to biochemical changes such as ascorbic acid degradation, pectin hydrolysis, polysaccharide breakdown and oxidation of reducing sugars, leading to the formation of weakly ionized acids. Similar patterns have been reported by Pavlova *et al.* (2013) [13] in raspberry and peach jams, and by Ayua *et al.* (2022) [2] in tomato jam, confirming the typical behavior of fruit-based spreads during storage.

Table 2: Effect of addition of sugar and honey on the Titratable acidity content of papaya and pineapple bread spread during storage

Treatment details	Treatment code	Titratable acidity (%)			
		Initial	1 MAS	2 MAS	3 MAS
Control -Papaya bread spread	T_1	1.070	1.120	1.180	1.200
Papaya (80%) + Sugar (20%)	T_2	0.660	0.682	0.714	0.732
Papaya (80%) + Honey (20%)	T_3	0.692	0.722	0.741	0.773
Control-Pineapple bread spread	T_4	1.040	1.062	1.096	1.110
Pineapple (80%) + Sugar (20%)	T_5	0.692	0.711	0.734	0.751
Pineapple (80%) + Honey (20%)	T_6	0.900	1.023	1.042	1.062
S.Em ±		0.042	0.044	0.047	0.047
CD at 5%		0.131	0.135	0.144	0.146

Ascorbic acid content (mg/100g)

Data given in Table 3 indicates that there was significant differences about Ascorbic content among all the treatments at initial and also during entire period of storage.

In papaya bread spreads ascorbic acid level decreased from 95-105 mg/100g initially to 75.92-79.81 mg/100g after three months and also in pineapple bread spreads showed a reduction from 69.32 -70.38 mg/100g at the initial stage to 50.97 - 52.79 mg/100g by the end of storage. This reduction is primarily attributed to the oxidation of ascorbic acid into dehydroascorbic acid, a phenomenon widely reported in fruit-based products. Bekele *et al.* (2020) [3] observed similar degradation in mango jam, while Chuah *et al*. (2008) [5] documented this trend earlier.

Table 3: Effect of addition of sugar and honey on the Ascorbic acid content of papaya and pineapple bread spread during storage

Treatment details	Treatment code	Ascorbic acid (mg/100g)			
		Initial	1 MAS	2 MAS	3 MAS
Control -Papaya bread spread	T_1	95.00	91.60	83.80	79.80
Papaya (80%) + Sugar (20%)	T_2	105.00	90.20	81.90	78.90
Papaya (80%) + Honey (20%)	T_3	100.10	91.10	83.30	75.90
Control-Pineapple bread spread	T_4	69.30	62.40	58.90	52.00
Pineapple (80%) + Sugar (20%)	T_5	70.60	63.60	56.50	51.00
Pineapple (80%) + Honey (20%)	T_6	70.40	63.30	55.30	52.80
S.Em ±		4.40	4.40	4.00	4.00
CD at 5%		13.59	13.50	12.45	12.26

Carotenoid content (mg/100g)
Data given in Table 4 indicates that there was significant differences about carotenoid content among all the treatments at initial and also during entire period of storage.

Carotenoid content values ranging from 4.428 to 7.775 mg/100g in papaya-based spreads and 0.817 to 1.124 mg/100g in pineapple-based formulations at the initial stages. After three months, these values decreased to 3.710 - 6.875 mg/100g in papaya-based spreads and 0.723 -1.023 mg/100g in pineapple-based formulations, due to oxidative degradation. This reduction is mainly due to oxidative degradation triggered by heat, light and oxygen. Similar losses have been reported in grapefruit jam (Igual *et al.*, 2013) [9], nettle juices (Bernas *et al.*, 2023) [4], Pitanga jam (Tobal *et al.*, 2019) [18], and cashew apple products (Zepka *et al.*, 2009) [19], highlighting carotenoids' sensitivity to storage conditions.

Table 4: Effect of addition of sugar and honey on the carotenoid content of papaya and pineapple bread spread during storage

Treatment details	Treatment code	Carotenoid (mg/100g)			
		Initial	1 MAS	2 MAS	3 MAS
Control -Papaya bread spread	T_1	7.775	7.353	6.995	6.875
Papaya (80%) + Sugar (20%)	T_2	4.517	3.972	3.756	3.71
Papaya (80%) + Honey (20%)	T_3	4.428	4.123	3.964	3.915
Control-Pineapple bread spread	T_4	1.124	1.099	1.060	1.023
Pineapple (80%) + Sugar (20%)	T_5	0.814	0.784	0.744	0.729
Pineapple (80%) + Honey (20%)	T_6	0.822	0.797	0.757	0.723
S.Em ±		0.171	0.158	0.149	0.141
CD at 5%		0.528	0.488	0.458	0.435

Sensory quality evaluation
Colour
Data given in Table 5 indicates that there was significant differences about colour score among all the treatments at initial and also during entire period of storage.

Treatment T_2 (Papaya 80% + Sugar 20%) consistently recorded the highest scores, beginning at 8.90 initially and decreasing to 8.33 by the third month, indicating better colour retention. In contrast, T_4 (Control-Pineapple bread spread) showed the lowest scores during the first two months, while T_3 Papaya (80%) + Honey (20%) recorded the lowest by the third month (6.00). The overall reduction in colour intensity is likely due to non-enzymatic browning and oxidation of phenolic compounds during storage. Similar declining trends have been reported in aonla jam (Gupta *et al.*, 2017) [8], mango-bael jam (Sharma, 2014) [15], and in bael jam (Ehsan *et al.*, 2003) [6], supporting the observed changes in visual quality.

Texture
Data given in Table 5 indicates that there was significant differences about Texture score among all the treatments at initial and also during entire period of storage.

T_5 Pineapple (80%) + Sugar (20%) consistently showed the highest texture scores, starting at 9.00 initially and reducing to 8.60 by the third month, indicating better texture retention. In contrast, T_1 (Control -Papaya bread spread) recorded the lowest scores at most stages, with a final score of 6.30. The overall decrease in texture quality is likely due to pectin hydrolysis during storage. Similar declining trends have been reported in orange-based low-calorie jam (Abolila *et al.*, 2015) [1], grapefruit-apple marmalade (Ehsan *et al.*, 2003) [6] and diet apple jam (Muhammad *et al.*, 2008) [11].

Taste
Data given in Table 6 indicates that there was significant differences about Taste score among all the treatments at initial and also during entire period of storage.

Initially, T_2 and T_3 recorded the highest scores (8.99), followed closely by T_5 and T_6, while T_4 had the lowest (6.63). Over time, T_3 maintained superior taste retention, scoring 8.20 by the third month. In contrast, T_4 consistently showed the lowest scores, decreasing to 6.00. The decline in taste quality may be due to changes in acidity and pH during storage. Similar trends were reported by Sharma *et al.* (2019) [16] in bael-mango chutney.

Overall acceptability
Data presented in Table 6 shows a gradual decline in overall acceptability of papaya and pineapple bread spreads during storage.

Initially, T_2 (Papaya pulp + Sugar 20%) scored highest (9.0), followed closely by T_3, T_5, and T_6, while T_4 (Control - Pineapple low sugar) had the lowest score (6.78). By the first month, T_3 Papaya (80%) + Honey (20%) led with 8.86, maintaining superiority through the second (8.75) and third months (8.55). T_4(6.15 - 6.78) consistently recorded the lowest scores across all stages. The decline in acceptability may be due to changes in acidity and pH during storage. Similar trends were reported by Sharma *et al.* (2019) [16] in bael-mango chutney. These findings affirm the impact of storage on sensory quality.

Table 5: Effect of addition of sugar and honey on the colour score & texture score of papaya and pineapple bread spread during storage

Treatment details	Treatment code	DAS (Days after storage)							
		Colour score (9point hedonic scale)				Texture score (9point hedonic scale)			
		0	30	60	90	0	30	60	90
Control -Papaya bread spread	T_1	8.80	7.17	7.00	6.80	6.85	6.74	6.53	6.30
Papaya (80%) + Sugar (20%)	T_2	8.90	8.60	8.45	8.33	8.85	8.50	8.30	8.10
Papaya (80%) + Honey (20%)	T_3	8.70	8.00	6.90	6.00	8.92	8.82	8.71	8.50
Control-Pineapple bread spread	T_4	7.55	6.85	6.71	6.33	6.92	6.81	6.51	6.34
Pineapple (80%) + Sugar (20%)	T_5	8.20	7.88	7.81	7.38	9.03	8.83	8.73	8.60
Pineapple (80%) + Honey (20%)	T_6	8.50	8.02	8.00	7.90	8.93	8.72	8.54	8.32
S.Em ±		0.26	0.23	0.26	0.26	0.26	0.26	0.26	0.26
CD at 5%		0.80	0.72	0.80	0.80	0.80	0.80	0.80	0.80

Table 6: Effect of addition of sugar and honey on the Taste score & Overall acceptability score of papaya and pineapple bread spread during storage

Treatment details	Treatment code	DAS (Days After Storage)							
		Taste score (9point hedonic scale)				Overall acceptability score (9point hedonic scale)			
		0	30	60	90	0	30	60	90
Control -Papaya bread spread	T_1	7.80	7.08	6.75	6.53	7.84	7.18	6.91	6.53
Papaya (80%) + Sugar (20%)	T_2	8.99	8.51	8.21	8.00	9.00	8.78	8.33	8.29
Papaya (80%) + Honey (20%)	T_3	8.99	8.83	8.51	8.20	8.95	8.86	8.75	8.55
Control-Pineapple bread spread	T_4	6.63	6.51	6.21	6.00	6.78	6.54	6.40	6.15
Pineapple (80%) + Sugar (20%)	T_5	8.93	8.84	8.42	8.00	8.64	8.60	8.34	8.18
Pineapple (80%) + Honey (20%)	T_6	8.90	8.22	8.11	7.80	8.58	8.26	8.20	7.94
S.Em ±		0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
CD at 5%		0.80	0.79	0.79	0.81	0.80	0.81	0.81	0.80

Conclusion
Based on the results from physico-chemical and sensory evaluations over three months of storage there was good retention of carotenoids and ascorbic acid content in papaya and pineapple jams made with 20% sugar or 20% honey which was also highly acceptable. Using osmotic treatment helped reduce the amount of added sweeteners without affecting the taste or texture. Even after storage, these jams kept their nutritional value, flavour, and safety, making them a healthy option for low-sugar bread spreads. This shows that fruit-based jams can be both tasty and suitable for health-conscious consumers.

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