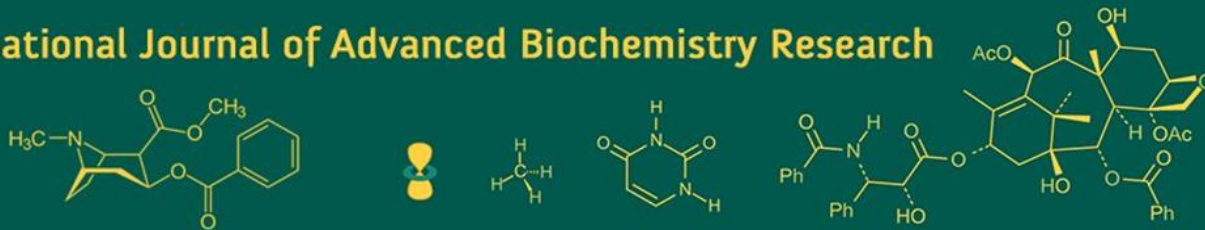


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Development, characterization and storage stability of antioxidant rich beetroot pomace based jam

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Abstract

Beetroot pomace, a byproduct of juice processing, is a rich source of dietary fiber, betalains an antioxidant compounds with potential application in functional food development. The present study aim to develop antioxidant rich jam using beetroot pomace and evaluate its nutritional quality, antioxidant properties, sensory acceptability and storage stability. Jams were prepared by blending beetroot pomace and papaya pulp in different proportions (100:0, 75:25, 25:75, 50:50 and 0:100). Sensory evaluation revealed that the jam contain 50 percent beetroot pomace (J1) and 50 percent papaya pulp (J3) received the highest overall acceptability score (8.00). the selected jam contained 43.13% moisture, 1.10 % protein, 1.92% crude fiber, 1.06 mg/100g ascorbic acid, 55.27 mg/100g total phenol , 29.42 mg/100g total flavonoid and exhibited 36.09% and 50.73 % antioxidant activity by DPPH and ABTS assay, respectively. Total betalain content of the supplemented jam was 38.70mg/100g. During 90 days of storage sensory quality remained acceptable, although betalain content decreased from 38.70 to 29.06 ,mg/q00g and antioxidant activity declined from 36.09 to 27.39 %. The study demonstrated that beetroot pomace can be successfully utilized for the development of nutritionally enriched jam with sensory quality and storage stability.

Keywords: Beetroot pomace, betalin, antioxidant, jam, storage stability, functional food

Introduction

In recent years, the food industry has witnessed a growing interest in utilizing agricultural byproducts to create value-added products, thereby reducing waste and promoting sustainability. Beetroot pomace, a by-product generated during the processing of beetroot into juice or slices, has garnered attention due to its rich nutritional composition and potential health benefits. This fibrous material, often overlooked and underutilized, contains significant amounts of dietary fiber, antioxidants, and bioactive compounds such as betalains. Betalains, specifically betacyanins and betaxanthins found in beetroot, have demonstrated antioxidant, antiinflammatory, and potentially anticancer properties in various studies (Manohar and Divakar, 2020; Smith *et al.*, 2020) [9, 16].

The concept of incorporating beetroot pomace into jams is particularly intriguing as jams are popular globally and consumed by a wide demographic, offering a convenient vehicle for delivering bioactive compounds to consumers. The utilization of beetroot pomace in jam production not only addresses environmental concerns by reducing waste but also enhances the nutritional profile of the final product. In market different type of jams are available but they are loaded with artificial colours, sugar and preservatives but by utilizing the beetroot pomace for jam production it provide natural colour and also the antioxidants although it is still loaded with sugar but beside this it provide antioxidants and also look tempting to consume. Furthermore, it presents an opportunity to develop innovative food products that cater to health-conscious consumers seeking functional foods. Despite these potential benefits, research exploring the feasibility, sensory attributes, and consumer acceptance of beetroot pomace-based jams remains limited.

This paper aims to review existing literature on the nutritional composition of beetroot pomace, the extraction methods of bioactive compounds, and the technological aspects involved in incorporating beetroot pomace into jams. Additionally, it will discuss the sensory characteristics, shelf-life of beetroot pomace-based jams. By addressing these aspects, this research contributes to expanding the knowledge base on sustainable food processing practices and exploring new avenues for utilizing agricultural by-products in functional food applications.

Material and Methods

Procurement, recovery and processing of beetroot

Fresh and fully mature 1 kg beetroot sourced from the local market in Palampur underwent initial cleaning to eliminate dust and extraneous matter, followed by removal of the calyx and peel. The peeled and sliced beetroot was processed using a Morphy Richard Maximo Juice Mixer Grinder to obtain

pomace. Subsequently, the extracted pomace was squeezed through muslin cloth to separate the juice component.

Development of jam

The jams were prepared by blending extracted beetroot pomace with papaya pulp in different ratio and has been presented below:

BP: PP	Ingredients (g)				
	Beetroot pomace	Papaya pulp	Sugar	Pectin	Citric acid
100: 0 (J1)	100	0	150	2	1.6
75: 25 (J2)	75	25	150	2	1.6
50: 50 (J3)	50	50	150	2	1.6
25: 75 (J4)	25	75	150	2	1.6
0: 100 (J5)	0	100	150	2	1.6

BP: Beetroot Pomace, PP: Papaya Pulp

Method for the preparation of jam

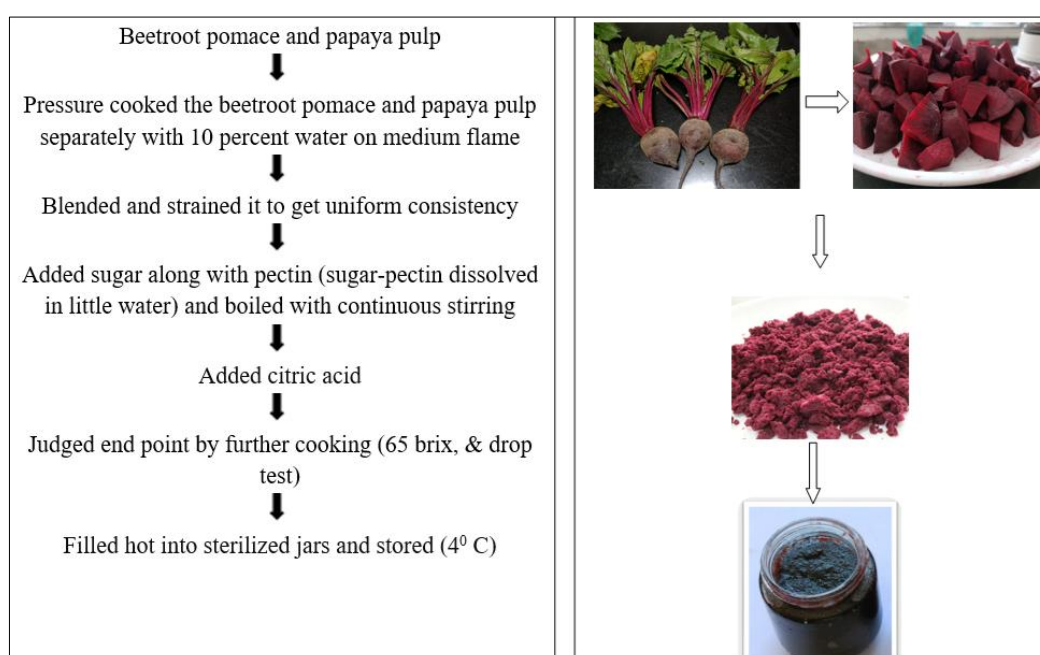


Fig 1: Flow sheet of fresh beetroot pomace-based jam

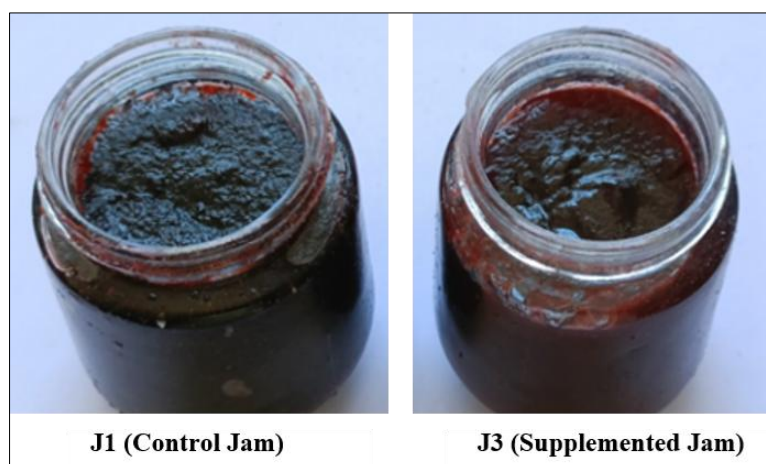


Plate 1: Appearance of fresh beetroot pomace-based jam

Sensory evaluation

A panel of 10 semi-trained judges evaluated beetroot pomace-enriched jams alongside control samples using a nine-point hedonic scale (Ranganna, 2020) [13] to assess colour,

appearance, texture, flavor, taste, and overall acceptability. Control samples followed standardized recipes, while supplemented samples included beetroot pomace.

Nutritional analysis

The moisture, crude fat, crude protein, crude fiber, total ash content and total carbohydrates were analyzed following AOAC (2010) standard methods for proximate constituents. Ascorbic acid content done by Ranganna (2007) [12] method. Total phenols and flavanoids content were determined by (Singleton *et al.* 1999) [15] and (Zhishen *et al.* 1999) [20] method. Total antioxidant activity by (Brand Williams *et al.* 1995) and by ABTS Radical Scavenging Assay (Re *et al.* 1999) [14] method. Total Betalain content was determined using (Stintzing *et al.* 2003) [17] method. The colour properties of the samples were assessed by measuring their L*, a*, and b* values using a Colour Flex meter with 45°/0° geometry, and standard illuminant C (Hunter Lab Colour Flex 150 by Hunter Associates Inc., USA).

Shelf- life stability and quality evaluation of stored jam

The developed beetroot pomace based jam was stored in glass jars at refrigerated temperature. Jam was analyzed fresh and after 30, 60 and 90 days of storage. The product was evaluated organoleptically by 10 panelists using nine-point hedonic rating scale. The developed product was nutritionally evaluated with respect to moisture, crude protein, crude fiber, total betalain content and antioxidant activity.

Statistical analysis

To analyze the data, OPSTAT software was employed. The mean and standard deviation for various characteristics of whole beetroot was computed. An independent sample *t*-test was conducted to compare nutritional, functional, and antioxidant characteristics between developed jam and their respective control samples. In the case of storage and sensory analysis, a one-way ANOVA test was used and compared at 5 percent level of significance to detect any notable variations in sensory attributes and nutritional characteristics of stored products during a 90-day storage period.

Result and Discussion

Recovery of peel, juice, pomace and pomace powder

Data pertaining to the recovery of peel, juice and fresh pomace is given in Table 1. The results revealed that from one kg of

whole beetroot 89.70g of peel, 415.60g of fresh pomace and 375.00 ml of juice. In the study, Kale *et al.* (2018) [7] has documented recovery of 91.0 percent of the beetroot which constituted of edible portion and 8.07 percent comprised waste.

Table 1: Recovery of peel, juice, fresh pomace and pomace powder per kg of whole beetroot

Parameters	Observations
Weight of beetroot without peel	885.00g
Weight of peel	115.00g
Weight of fresh pomace content	415.60g
Weight of juice content	375.00ml

Nutritional and antioxidant properties of whole beetroot

The moisture content in beetroot was determined to be 88.5±1.39 percent (Table 2), which aligns with the findings of Bunkar *et al.* (2020) [5], where they recorded a moisture content of 88.00 percent in beetroot. The protein content in beetroot was found to be 1.68±0.07 percent, and this value is consistent with the results reported by Yashwant (2015) [19] and Mirmiran *et al.* (2020) [10]. Beetroot contained 0.27±0.06 percent fat and 2.43±0.35 percent fiber, which closely resembles the values of 0.20 percent fat and 2.8 percent fiber documented by Bunkar *et al.* (2020) [5]. Additionally, the total ash content in beetroot was identified as 1.43±0.22 percent, and this figure is in line with the observations made by Kale *et al.* (2018) [7]. The total carbohydrate content in beetroot was 8.12±0.78 percent, which closely resembled the value (9.56%) reported by Mirmiran *et al.* (2020) [10].

Beetroot had high moisture content (88.50%), which is typical for root vegetables, contributing to its short shelf life and need for immediate processing (Table 2). Its moderate protein (1.68%), fiber (2.43%), and ash (1.43%) content reflect its nutritional value, aligning with previous findings by Bunkar *et al.* (2020) [5] and Kale *et al.* (2018) [7]. The carbohydrate content (8.12%) makes beetroot a natural source of energy (Table 2).

Table 2: Proximate composition and antioxidant properties of whole beetroot

Parameters	Beetroot
Moisture (%)	88.50±1.39
Crude Protein (%)	1.68±0.07
Crude Fat (%)	0.27±0.06
Crude Fiber (%)	2.43±0.35
Total Ash(%)	1.43±0.22
Total Carbohydrates (%)	8.12±0.78
Ascorbic acid (mg/100g)	4.46±0.38
Betacyanin (mg/100g)	418.08±2.10
Betaxanthin (mg/100g)	235.77±6.47
Total Betalain (mg/100g)	653.85±8.44
Total Phenols (mg/100g)	71.96±0.55
Total Flavonoids (mg/100g)	41.16±1.49
DPPH (%)	59.27±0.30
ABTS (%)	76.66±0.70

Values are expressed as Mean ± SD

Beetroot is rich in bioactive compounds, including phenolic acids, flavonoids, and betalains, which exhibit strong antioxidative properties. The ascorbic acid content in beetroot was 4.46±0.38 mg/100g, aligning with Kaur *et al.* (2021) [8], who reported 4.3 mg/100g. Beetroot contains 653.85±8.44 mg/100g of betalains, comprising 418.08±8 mg/100g of betacyanins and 235.77±6.47 mg/100g of betaxanthins. These values are consistent with Bucur *et al.* (2016) [4], who reported 462–838 mg/100g across seasons. Total phenolic content was

71.96±0.55 mg GAE/100g, and flavonoid content was 41.16±1.49 mg QE/100g, closely matching Kaur *et al.* (2021) [8], who reported 77.88 mg GAE/100g of phenols and 42.75 mg QE/100g of flavonoids.

Sensory evaluation of developed jams

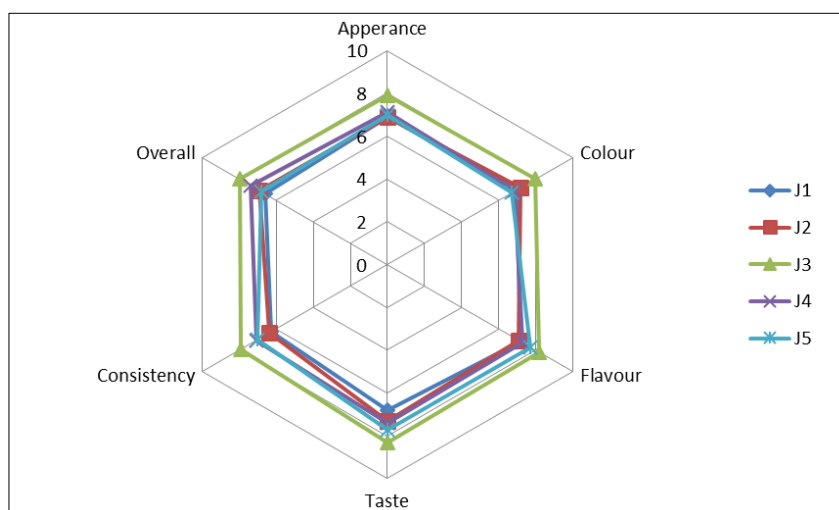
Table 3 represents the sensory scores of jams developed by using fresh beetroot pomace and papaya pulp in varying proportions.

Table 3: Sensory evaluation of jam developed using fresh beetroot pomace

BP: PP	Appearance	Colour	Flavour	Taste	Consistency	Overall acceptability
100:0 (J1)	6.90	7.00	7.20	6.80	6.30	6.60
75:25 (J2)	6.90	7.20	7.10	7.30	6.40	6.90
50:50 (J3)	7.90	8.00	8.20	8.30	7.90	8.00
25:75 (J4)	7.10	6.90	7.30	7.40	7.10	7.40
0:100 (J5)	7.00	6.70	7.70	7.70	7.00	6.80
CD Value	0.62	0.51	0.43	0.58	0.47	0.45

BP: Beetroot Pomace, PP: Papaya Pulp, Significant at 5% level of significance ($p < 0.05$)

Treatment J3 (50% beetroot pomace and 50% papaya) scored highest in appearance (7.90), color (8.00), flavor (8.20), taste (8.30), and overall acceptability (8.00) among J1, J2, J3, J4, and J5. It was selected for further analysis due to its superior sensory evaluation scores (figure 2).

**Fig 2:** Sensory evaluation of jam developed using fresh beetroot pomace

Proximate composition

The proximate composition of jam in comparison to control has been represented in Table 4. The results showed that there was a slight increase in the moisture content of the supplemented jam (43.13%) than the control jam (41.76%) but this difference was non-significant. With respect to protein, the value for control jam (1.32%) was significantly increased as compared to beetroot pomace supplemented jam (1.1%), this is because beetroot pomace has a greater protein content than papaya. Akath *et al.* (2010) [1] reported that the protein content of papaya

was 0.39 percent. The fat content of control jam and supplemented jam was found to be non-significant, because fruits and vegetables contain very low amounts of fat. Crude fiber in control jam and supplemented jam was 2.15 and 1.95 percent respectively. The crude fiber was significantly higher in control jam because beetroot pomace contains more fiber content than papaya *i.e.*, 2.10 percent in beetroot pomace (Abdo *et al.* 2020) [21] and 1.52 percent in papaya (Akath *et al.* 2010) [1]. The ash and carbohydrate content of control jam was slightly higher than the J3 jam, but the difference was non-significant.

Table 4: Proximate composition (%) of fresh beetroot pomace-based jam

Parameters	Jam		t-value (p value)
	J1	J3	
Moisture	41.76	43.13	0.46 ^{NS} (0.66)
Crude Protein	1.32	1.10	3.49(0.02)
Crude Fat	0.15	0.15	0.22 ^{NS} (0.82)
Crude Fiber	2.15	1.92	3.66(0.021)
Total Ash	0.93	0.87	0.46 ^{NS} (0.66)
Total Carbohydrates	55.83	55.08	2.20 ^{NS} (0.009)

J1- control jam, J3- supplemented jam, Significant at 5% level of significance ($p < 0.05$), NS- Non-significant

Antioxidant properties

Beetroot pomace contained a high concentration of antioxidants, including phenols, flavonoids, and ascorbic acid. The antioxidant properties of beetroot pomace-based jam has been expressed in Table 5. The ascorbic acid content in the supplemented jam was noted to be 1.06 mg/100g, while the control jam had a 1.20 times lower amount of ascorbic acid, observed to be 0.86 mg/100g. The higher content of ascorbic

acid in the supplemented jam can be attributed to its composition, which consists of a blend of 50 percent beetroot pomace and 50 percent papaya pulp. Papaya pulp naturally contains a higher concentration of ascorbic acid compared to beetroot pomace, which is the sole component in the control jam. Consequently, the control jam exhibited a lower level of ascorbic acid content when compared with the blended jam, primarily due to the absence of the ascorbic acid-rich papaya

pulp in its composition. Igual *et al.* (2016) [6] observed a significant disparity in the levels of ascorbic acid between jams, suggesting that the process of making jam led to the conversion of ascorbic acid to dehydro-ascorbic acid, which was more pronounced than what was seen in fresh grapefruit samples.

The processing of beetroot pomace into jam resulted in an increase in both total phenol content (61.35 mg/100g) and flavonoid content (38.84 mg/100g) compared to the initial values of 59.40 mg/100g and 34.93 mg/100g, respectively. This enhancement is attributed to the concentration of the food matrix and the disruption of cell walls during the jam-making process, facilitating better extraction of phenolic compounds. However, when comparing the supplemented jam to control jam, a significant decrease in phenol and flavonoid content was observed in the supplemented jam (55.27 mg/100g and 29.42 mg/100g, respectively). This difference can be attributed to the lower phenolic and flavonoid content in papaya (35.56 mg/100g and 22.53 mg/100g, as reported by Addai *et al.* (2013), and the supplemented jam contained 50 percent of papaya pulp in place of beetroot pomace.

The antioxidant potential of beetroot is intricately tied to its inherent bioactive compounds. While there was a noticeable increase in the overall content of total phenols and flavonoids.

The antioxidant activity assessed by both DPPH and ABTS methods also displayed an upward trend. This increase was closely related to the elevated content of these bioactive compounds. Specifically, the antioxidant activity measured by DPPH and ABTS assays was significantly higher in the control jam at 40.27 and 56.26 percent, respectively, compared to the supplemented jam, which exhibited values of 36.09 and 50.73 percent respectively. The disparity can be attributed to the inclusion of papaya in the jam, as papaya contains lower levels of phenols and flavonoids compared to beetroot pomace, resulting in a reduced antioxidant activity in the supplemented jam.

Table 5: Antioxidant properties of fresh beetroot pomace-based jam

Parameters	Jam		t-value (p value)
	J1	J3	
Ascorbic acid (mg/100g)	0.86	1.06	1.97 (0.04)
Total Phenols (mg/100g)	61.35	55.27	7.74 (<0.001)
Total Flavonoids (mg/100g)	38.84	29.42	14.70 (<0.001)
DPPH (%)	40.27	36.09	3.99 (<0.001)
ABTS (%)	56.26	50.73	13.8 (<0.001)

J1- control jam, J3- supplemented jam, Significant at 5% level of significance ($p < 0.05$)

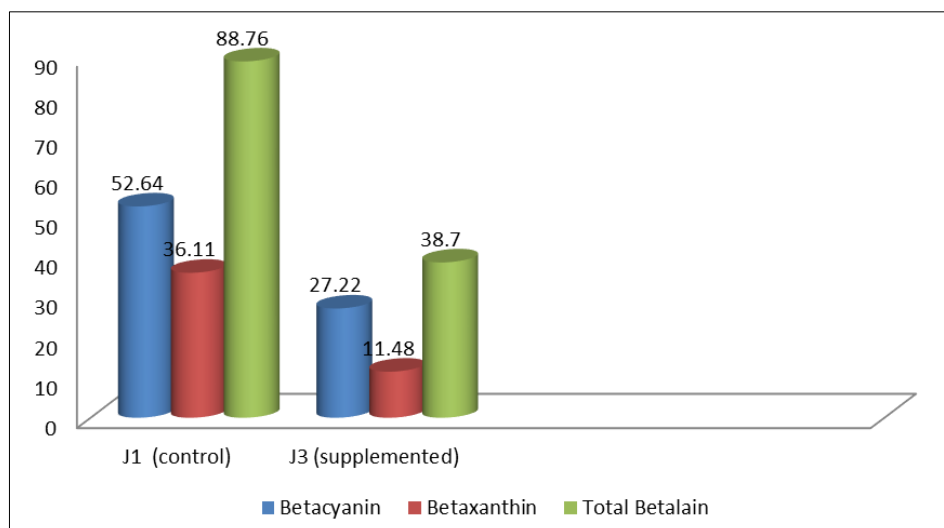


Fig 3: Effect of processing on betalain content of jam

The effect of processing on betalain content was observed in jam, which is represented in figure 3. As is evident from the data control jam contained significantly higher betalain (52.64 mg/100g) when compared to supplemented jam (27.22mg/100g). The betacyanin and betaxanthin content of control jam were 36.11 mg/100g and 88.76 mg/100g respectively, which were also higher than supplemented jam (11.48 and 38.70 mg/100g). Oksuz *et al.* (2015) noted that the application of heat in the preparation of red beet jam resulted in the transformation of betalains into alternative compounds, including betanidin and its breakdown products, such as isobetanin, neobetainin, and vulgaxanthin. The betalain content experienced a reduction as a result of heat treatment, in contrast to the betalain content found in fresh beetroot pomace. However, in the case of supplemented jam, the betalain levels were reduced due to the absence of betalain pigments in papaya. Consequently, the control jam, which exclusively comprised of 100 percent beetroot pomace, displayed elevated betalain content compared to the supplemented jam, which consisted of

a mixture of 50 percent beetroot pomace and 50 percent papaya pulp.

Colour analysis of jam

Table 4.21 represents the effect of processing on colour of jam and toffee. L^* , a^* and b^* values were significantly higher in supplemented jam as compared to control. The reduced lightness value in the control jam can be attributed to its exclusive composition of beetroot pomace, which, upon cooking, initiated a Maillard reaction, resulting in a darker appearance. Kaur (2021) reported the colour value of L^* at 19.54, a^* at 13.14 and b^* at -14.11 in beetroot jam.

Table 6: Effect of processing on colour characteristics of jam

Parameter	Control	Jam	t-value
L^*	12.16	15.27	73.76(<0.001)
a^*	1.54	3.04	112.25(<0.001)
b^*	-0.26	0.14	31.75(<0.001)

Significant at 5% level of significance ($p < 0.05$)

Storage stability and quality evaluation of jam

1. Sensory evaluation

The control and supplemented jam were stored for a period of 90 days under refrigerator. Table 6 depicts the effect of storage on sensory score of control and supplemented jam

Table 7: Effect of storage on sensory attributes of fresh beetroot pomace-based jam

Parameters	Treatments	0 day	30 days	60 days	90 days	CD value
Appearance	Control	6.90	6.80	6.70	6.30	0.39
	Supplemented	7.90	7.90	7.60	7.60	0.42
Colour	Control	7.00	6.90	6.50	6.10	0.34
	Supplemented	8.00	7.80	7.30	7.10	0.38
Flavour	Control	7.20	7.10	7.10	6.90	0.39 ^{NS}
	Supplemented	8.20	8.00	8.00	7.90	0.10 ^{NS}
Taste	Control	6.80	6.80	6.60	6.70	0.24 ^{NS}
	Supplemented	8.30	8.30	8.20	8.10	0.26 ^{NS}
Consistency	Control	6.30	6.20	6.10	6.10	0.20 ^{NS}
	Supplemented	7.90	7.80	7.70	7.60	0.36 ^{NS}
Overall acceptability	Control	6.80	6.70	6.60	6.40	0.48 ^{NS}
	Supplemented	8.00	7.90	7.70	7.60	0.57 ^{NS}

Control (J1): 100 percent beetroot pomace, supplemented (J3)- 50:50 beetroot pomace: papaya pulp, Significant at 5% level of significance ($p < 0.05$), NS- Non- significant

The appearance scores for both the control and supplemented jam exhibited a statistically significant decline during storage. In the case of the control jam, the appearance score decreased from 6.90 to 6.30, while the supplemented jam decreased from an initial score of 7.90 to 7.60. Similarly, the colour scores for both the control and supplemented jam showed a significant decrease, with the control jam declining from 7.00 to 6.10, and the supplemented jam declining from an initial score of 8.00 to 7.10. This alteration in colour was attributed to the degradation of betalain compounds over the storage period. The attributes of flavor, taste, and consistency in both the control and supplemented jams exhibited a slight decline over time, although these changes did not reach statistical significance.

Furthermore, the overall acceptability scores for both types of jam also showed a decrease that was not statistically significant. Consequently, it was concluded that both the control and supplemented jams remained acceptable for consumption even after a 90-day storage period.

2. Nutritional evaluation

The effect of storage on nutritional and antioxidant properties of jam has been summarized in Table 7. The results for the jam were found to be consistent with respect to moisture, protein and fiber. The storage study revealed that there was slight change observed in nutritional composition of jam up to 90 days, but the difference was non-significant.

Table 8: Effect of storage on nutritional and antioxidant properties of fresh beetroot pomace- based jam

Parameters	Treatments	0 day	30 days	60 days	90 days	CD Value
Moisture (%)	Control	41.76	41.76	42.78	41.79	2.97
	Supplemented	43.13	43.17	42.59	41.79	2.97
Crude Protein (%)	Control	1.32	1.29	1.21	1.14	0.90
	Supplemented	1.10	1.00	0.80	0.70	0.90
Crude Fiber (%)	Control	2.15	2.10	2.08	2.01	0.08
	Supplemented	1.92	1.89	1.90	1.91	0.08
Betacyanin (mg/100g)	Control	52.64	50.38	49.34	47.92	1.56
	Supplemented	27.22	25.55	23.54	20.27	1.56
Betaxanthin (mg/100g)	Control	36.11	35.15	33.19	30.65	0.97
	Supplemented	11.48	10.46	9.55	8.79	0.97
Total Betalain (mg/100g)	Control	88.76	85.53	82.54	78.57	1.82
	Supplemented	38.70	36.01	33.09	29.06	1.82
DPPH (%)	Control	40.27	38.51	36.74	34.21	1.64
	Supplemented	36.09	33.44	30.45	27.39	1.64

Control (J1): 100 percent beetroot pomace, supplemented (J3)- 50:50 beetroot pomace: papaya pulp, Significant at 5% level of significance ($p < 0.05$)

It was observed that the betalain content in both the control and the supplemented jam decreased from 88.76 to 78.57 mg/100g in control and 38.70 to 29.06 mg/100g in supplemented jam as the storage time progressed from 0 to 90 days. Refrigeration helps extend the shelf life of products and preserves their quality, but it doesn't provide an indefinite guarantee against the degradation of sensitive compounds like betalains. Over time, a combination of factors, including oxidation, temperature, and light exposure can lead to a decrease in betalain content even

under refrigerated conditions. The antioxidant activity of both the stored control jam and the supplemented jam exhibited a decrease, declining from 40.27 to 34.21 percent for the control and from 36.09 to 27.39 percent for the supplemented. This decline can be attributed to the fact that antioxidant capacity relies on the presence of bioactive compounds, and as the betalain content decreased, it subsequently led to a reduction in the antioxidant activity. A study conducted by Anwar *et al.* (2021) found that the antioxidant activity in papaya jam

supplemented with date pit powder decreased over a 90 days storage periods because during storage phenolic compounds are easily oxidized and become one of the reasons for the reduction of antioxidant activity.

Conclusion

The study demonstrated the potential of beetroot pomace for value addition through the development of jam enhances the nutritional and antioxidant properties. The developed jam exhibited appreciable levels of antioxidants, phenols, flavonoid and betalain content while remaining organoleptically acceptance through out 90 days of storage. Therefore beetroot pomace based jam represents a promising functional food product for the utilization of beetroot processing by products.

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