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Biochemical characterization and nutritional evaluation of a functional high-protein fruit bar using apricot-plum

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ABSTRACT

The present investigation was carried out to develop and characterize functional high-protein fruit bars enriched with bioactive compounds. Apricot powder, plum powder, Spirulina platensis, malted amaranth, dates, and dry fruits were utilized to formulate seven treatment combinations, which were evaluated for ascorbic acid, total phenolics, anthocyanins, and β-carotene contents during 90 days of storage. Apricot-based formulations exhibited significantly higher ascorbic acid (15.72 mg/100 g) and β-carotene (57.78 mg/100 g) levels, while plum-based treatments recorded the maximum phenolic content (574.78 mg GAE/100 g). Anthocyanin content was also greater in apricot-rich bars (45.32 mg/100 g). Storage led to a gradual decline in all bioactive components, with losses attributed to oxidation and degradation of sensitive compounds. Despite these reductions, the bars retained appreciable nutritional and functional qualities over the storage period. The study highlights the potential of fruit–protein blends as convenient, nutrient-rich snack options, meeting consumer preferences for health-oriented functional foods. Further improvements in storage stability and sensory quality could enhance their commercial viability.

Keywords: *Anthocyanin, Apricot, Bioactive components, Dates, Plum, Storage stability.*

Introduction

The increasing consumer demand for nutrient-dense, convenient, and health-promoting foods has led to the rapid growth of the functional food industry. Among various functional food products, protein-enriched snacks have gained significant attention due to their role in promoting satiety, supporting muscle health, and contributing to overall nutritional well-being. Proteins are essential macronutrients that not only serve as building blocks for growth and repair but also play vital roles in metabolic regulation and immune function. In particular, high-protein snack formulations are increasingly sought after by athletes, health-conscious individuals, and populations with elevated protein requirements.

Fruit bars, traditionally recognized for their natural sweetness, fiber content, and abundance of bioactive compounds such as antioxidants, vitamins, and minerals, offer an ideal matrix for the incorporation of functional ingredients. The health benefits and natural appeal of these bars have contributed positively to consumer perception, positioning them as promising functional food products (1).

By enriching fruit-based bars with high-quality protein sources, it is possible to develop a product that combines the health benefits of fruits with the functional properties of proteins, thereby creating a nutritionally balanced and appealing alternative to conventional snacks. These bars help manage hunger while offering a nutritious alternative to traditional meals (2). Such formulations not only address energy needs but also provide added health benefits, including weight management, muscle maintenance, and improved metabolic health.

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Materials and methods

Preparation of fruit bars

Functional protein-rich fruit-bars were prepared from foam mat dried plum and apricot powder, malted amaranth, *Spirulina plantensis*, dates, and dry fruit mix. Seven treatment combinations were formulated viz. T_1 (60:00:05:15::AP:PP:SP:MA), T_2 (50:10:05:15::AP:PP:SP:MA), T_3 (40:20:05:15::AP:PP:SP:MA), T_4 (30:30:05:15::AP:PP:SP:MA), T_5 (20:40:05:15::AP:PP:SP:MA), T_6 (10:50:05:15::AP:PP:SP:MA), T_7 (00:60:05:15::AP:PP:SP:MA). The nutri-bar was prepared by mixing all the ingredients with constant stirring until completely homogenized. The mixture was then spread in a stainless steel tray having dimensions 28×23×2.5 cm and wrapped using cling film. The tray was then placed in the refrigerator for an hour until hardening. The obtained mixture was taken out and cut into bars.

Methods of analysis

2.1 Ascorbic acid (AOAC, 2012)

Ascorbic acid content was determined by the procedure of Sadasivam and Manicham (3) using 2,6-dichlorophenol indophenol dye. The sample was extracted in a 4 per cent oxalic acid solution and titrated with the standard dye to a pink colour that persisted for 15 seconds.

The results were expressed as mg/100g sample.

Dye factor = 0.05/ Titre

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{volume made up}}{\text{Aliquot of extract taken x weight of sample}} \times 100$$

2.2 Total anthocyanin content

Total anthocyanins were determined according to the method given by Ranganna (4). 10g of sample was blended with 50 ml of ethanolic hydrochloric acid, transferred to 100ml volumetric flask and made upto volume. The extracted samples were stored overnight in the refrigerator at 4°C, filtered through Whatman filter paper no. 1 and OD (optical density) of the filtrate was recorded at 535 nm. The anthocyanin content was calculated as per the following equations:

$$\text{Total (OD/100g)} = \frac{\text{OD x Volume made up}}{\text{weight of the sample}} \times 100$$

$$\text{Total anthocyanins (mg/100g} = \frac{\text{Total OD/100g}}{98.2} \times 100$$

2.3 β-Carotene

For the determination of β-Carotene, the procedure of Srivastava and Kumar (5) was followed. 5g of the sample was taken, dissolved in 10-15 ml of AR grade acetone with the help of pestle and mortar, and a few crystals of anhydrous sodium sulphate were added. The supernatant was decanted into a beaker. The process was repeated twice, and the combined supernatant was transferred into a separating funnel, then 10-15 ml of petroleum ether was added and mixed thoroughly. Two layers are separated on standing. The lower layer was discarded, and the upper layer was collected in a 100mL volumetric flask. The volume was made up to 100 ml with petroleum ether, and the optical density was recorded at 452 nm using petroleum ether as a blank. The β-Carotene was calculated using the formula:

$$\text{β-Carotene(mg/100g)} = \frac{\text{Optical density x 13.9 x 100000 x 100}}{\text{weight of sample x 560 x 1000}} \times 100$$

2.4 Total phenolic content

For the determination of total phenol, the procedure of Icyer (2012) was followed,. 1 g of the powder was weighed into a screw-caped vial. 10 ml of distilled boiling water was added to the vial, and the extraction was maintained at 100°C for 5 min. The mixture was cooled to room temperature, filtered through a 0.45 mm filter, and mixed with 0.5 ml of Folin Ciocalteu's reagent. The mixture was left in the dark for 7 min, and then 1.5 ml of 20% (w/w) sodium carbonate solution was added to the sample. The mixture was left in the dark for another 2 hours, and the absorbance value of the sample was measured at a wavelength of 765 nm using a UV/Vis spectrophotometer.

1. Results and Discussion

1.1 Ascorbic acid content

On analyzing the mean ascorbic acid content of the functional high-protein fruit bar, the highest mean ascorbic acid content of 15.72 mg per 100g was recorded in treatment T_1 (60:00:05:15::AP:PP:SP:MA), whereas, treatment T_7 (00:60:05:15::AP:PP:SP:MA) exhibited the lowest mean ascorbic acid content of 14.79 mg per 100g. This trend is attributed to the higher ascorbic acid content of apricot powder in comparison to plum powder. As the proportion of apricot powder decreased and plum content increased across treatments, a corresponding decrease in ascorbic acid content was evident in the fruit bars. These findings are in line with Srivastava *et al.* (7), who reported a decline in ascorbic acid with decreasing guava pulp in guava-orange fruit bars, as guava inherently contains more ascorbic acid than orange.

Significant decrease in ascorbic acid content from 16.14 to 14.30 mg per 100g was noticed during the 90 day storage period. This reduction can be attributed to the oxidation of ascorbic acid to dehydroascorbic acid, which subsequently degrades into 2,3-diketogluconic acid, and eventually into furfural compounds. These compounds may further participate in non-enzymatic browning reactions, leading to overall quality deterioration during storage. Similar results of a decrease in ascorbic acid content during storage were reported by Dhiman *et al.* (8) in pumpkin bar and Naz *et al.* (9) in jamun leather.

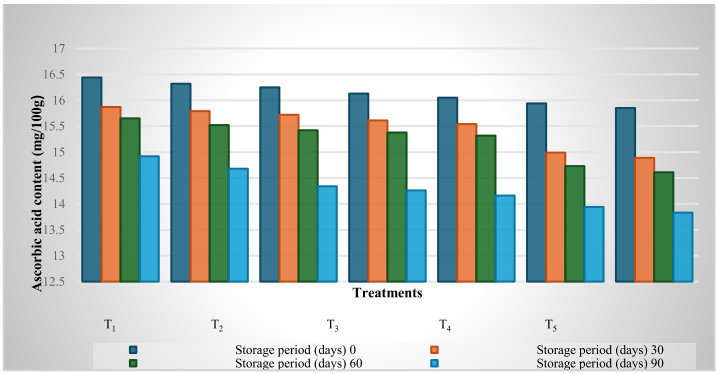

Fig. 1 Effect of blending and storage on ascorbic acid content (mg/100g) of functional protein-rich fruit bar

1.2 Total phenolic content

The highest mean total phenolic content of 574.78 mg GAE per 100g was recorded in treatment T_7 (00:60:05:15::AP:PP:SP:MA), whereas, lowest mean total phenolic content of 240.79 mg GAE per 100g was recorded in treatment T_1 (60:00:05:15::AP:PP:SP:MA). This pattern indicates that the increase in plum powder, which is richer in phenolic compounds compared to apricot powder, led to a higher total phenolic content in the fruit bar. The observed trend supports the fact that plum powder contributes significantly to the antioxidant profile of the formulation. These results are consistent with those reported by Doiphode and Mane (10), who found an increase in total phenolic content in snack bars as the concentration of spirulina increased and oats decreased. Similarly, Sahu (11) reported enhanced phenolic content in apple energy bars with the inclusion of phenolic-rich ingredients.

The mean total phenolic content decreased significantly from 414.97 mg GAE per 100 g to 403.32 mg GAE per 100 g during the storage period of 90 days. This decline is likely due to the increase in product moisture, which may cause dilution of phenolic compounds and promote oxidative degradation. Phenolic compounds are known to be sensitive to storage conditions, especially in high-humidity environments. Similar results were also reported by Meyer *et al.* (12) in strawberry –kiwi leathers, Siddique *et al.* (13) in protein-enriched composite cereal bar.

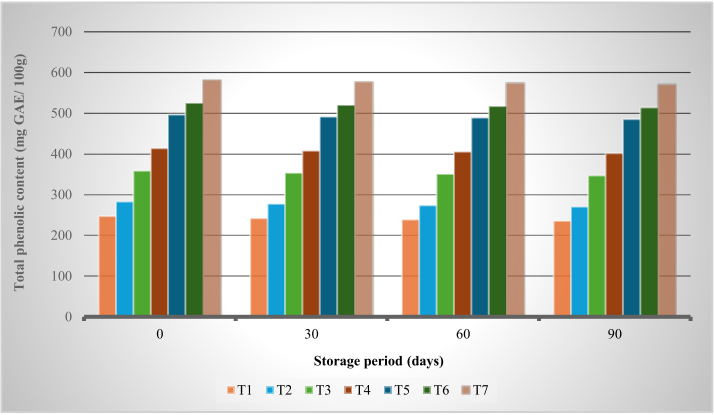

Fig. 2 Effect of blending and storage on total phenolic content (mg GAE/100g) of functional protein rich fruit-bar

1.3 Anthocyanin content

A notable difference in anthocyanin content was observed across treatments, with treatment T_1 (60:00:05:15::AP:PP:SP:MA) contained the highest level at 45.32 mg per 100g, and treatment T_7 (00:60:05:15::AP:PP:SP:MA) exhibited the lowest mean anthocyanin content at 32.38 mg per 100g which, might be due to the presence of higher anthocyanin content in apricot powder than in plum powder, so as the content of apricot powder in treatments was decreased, the anthocyanin content of the fruit bar was also decreased. Similar results of an increase in anthocyanin content were reported by Mannikeri (14) in jamun fruit bar fortified with quinoa and by Rahul *et al.* (15) in guava-jamun cheese toffee.

A significant decline in anthocyanin content was recorded during the 90-day storage period, with values dropping from 42.51 mg/100g to 35.10 mg/100g. This reduction can be attributed to multiple factors that influence anthocyanin stability, such as acidity, phenolic compounds, sugar and sugar degradation products, oxygen, and ascorbic acid (16). These findings are consistent with Govinda Prabhu (17), who observed anthocyanin degradation in jamun fruit bars over time.

Table 1: Effect of blending and storage on anthocyanin (mg/100g) content of functional protein- rich fruit bar

Treatments	Storage period (days)				Mean
	0	30	60	90	
T_1 (60:00:05:15::AP:PP:SP:MA)	49.14	46.15	44.74	41.28	**45.32**
T_2 (50:10:05:15::AP:PP:SP:MA)	46.93	44.02	42.49	39.02	**43.11**
T_3 (40:20:05:15::AP:PP:SP:MA)	44.72	41.75	40.27	37.78	**41.13**
T_4 (30:30:05:15::AP:PP:SP:MA)	42.51	39.60	39.15	35.68	**39.23**
T_5 (20:40:05:15::AP:PP:SP:MA)	40.31	37.35	37.88	32.42	**36.99**
T_6 (10:50:05:15::AP:PP:SP:MA)	38.10	35.15	33.71	30.26	**34.30**
T_7 (00:60:05:15::AP:PP:SP:MA)	35.89	32.91	31.44	29.28	**32.38**
Mean	**42.51**	**39.56**	**38.52**	**35.10**	
Effects $CD_{(0.05)}$ SE(m)					
Treatment 0.02 0.01					
Storage 0.03 0.01					
Treatment x Storage 0.04 0.01					

AP-Apricot Powder; PP-Plum Powder; SP- Spirulina Powder; MA- Malted Amaranth

1.4 β-carotene content

The maximum mean β-carotene content of 57.78 mg per 100g was recorded in treatment T_1 (60:00:05:15::AP:PP:SP:MA), whereas, minimum mean β-carotene content of 51.40 mg per 100g was recorded in treatment T_7 (00:60:05:15::AP:PP:SP:MA).This trend suggests that β-carotene content increased with the proportion of apricot powder, which possesses higher β-carotene levels compared to plum powder. Thus, treatments with higher apricot content exhibited significantly elevated β-carotene concentrations.

These findings are in agreement with Sucheta *et al.* (18), who reported increased carotenoid content in Guava-Mango cheese toffees with higher mango pulp. Ashraf *et al.* (19) also reported similar results in apricot powder blended nut crackers.

The mean β-carotene content decreased significantly from 59.50 mg per 100 g to 51.17 mg per 100 g during the storage period of 90 days, which might be due to the oxidative degradation of colour pigments (20). Similar results were also reported by Gurung *et al.* (21) in pumpkin puree fortified biscuits, Bertagnolli *et al.* (22) in guava peel flour (GPF) fortified biscuits.

Table 2: Effect of blending and storage on β-Carotene (mg/100g) content of functional protein- rich fruit bar

Treatments	Storage period (days)				Mean
	0	30	60	90	
T_1 (60:00:05:15::AP:PP:SP:MA)	62.78	58.61	55.52	54.22	**57.78**
T_2 (50:10:05:15::AP:PP:SP:MA)	61.69	57.73	54.65	53.41	**56.87**
T_3 (40:20:05:15::AP:PP:SP:MA)	60.59	56.61	53.52	52.28	**55.75**
T_4 (30:30:05:15::AP:PP:SP:MA)	59.50	55.54	52.47	51.21	**54.68**
T_5 (20:40:05:15::AP:PP:SP:MA)	58.42	54.45	51.41	50.16	**53.61**
T_6 (10:50:05:15::AP:PP:SP:MA)	57.33	53.37	50.29	49.03	**52.50**
T_7 (00:60:05:15::AP:PP:SP:MA)	56.24	52.25	49.18	47.93	**51.40**
Mean	**59.50**	**55.50**	**52.43**	**51.17**	
Effects $CD_{(0.05)}$ SE(m)					
Treatment 0.02 0.01					
Storage 0.03 0.01					
Treatment x Storage 0.05 0.02					

AP-Apricot Powder; PP-Plum Powder; SP- Spirulina Powder; MA- Malted Amaranth

Conclusion

The present study revealed that functional high-protein fruit bars prepared with apricot powder, plum powder, Spirulina, malted amaranth, dates, and dry fruits are nutritionally rich and bioactive compound–dense. Apricot powder significantly enhanced ascorbic acid and β-carotene levels, whereas plum powder contributed more to total phenolic content. Anthocyanin concentration was also higher in apricot-based treatments. However, all bioactive compounds, including ascorbic acid, phenolics, anthocyanins, and β-carotene, showed a gradual reduction during 90 days of storage due to oxidative and degradative changes. Overall, the study demonstrated that blending fruit powders with protein-rich and functional ingredients can yield a stable, health-promoting, and convenient snack product, aligning well with consumer demand for functional foods. Future work should focus on improving storage stability and sensory acceptability to strengthen commercial applicability.

Future scope of the study

Future studies can explore advanced drying and packaging techniques to enhance the stability of bioactive compounds. Incorporating additional protein sources or functional ingredients may further improve nutritional quality. Economic feasibility and scale-up trials will support commercial development of the product.

Conflict of interest:

The authors declare no conflict of interest

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