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Development, physicochemical quality analysis, and nutritional evaluation of mango and date fruit bars, enriched with quinoa

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Abstract

Food bars made with variety of fruits and pseudocereals offer both nutritional and bioactive contents. This study aimed to develop and evaluate *quinoa*-based functional fruit bars incorporating mango and dates, at three *quinoa* flour concentrations (10%, 20%, and 30%). The research employed proximate, mineral, total sugars, reducing and non-reducing sugars, in vitro starch digestibility, calorific value, water holding capacity, brix content, color, microbiological safety, sensory, texture analysis and storage studies over a 45-day period following standard protocols. For *quinoa*-based fruit bars, protein content ranged from 14.51% (day 0) to 8.88% (day 45) across treatments, while calorific values decreased from 316.41 kcal to 297.90 kcal. Moisture content declined significantly, from 18.253% on day 0 to 14.130% on day 45, leading to an increase in hardness value from 233.77 g to 635.00 g. Sensory analysis revealed that the bar with 20% *quinoa* flour were considered as the most acceptable, achieving the highest scores for aroma and texture throughout storage. For mango-based fruit bars, protein content ranged from 13.21% (day 0) to 9.42% (day 45), and calorific values varied from 314.78 kcal to 301.43 kcal. Moisture content decreased from 17.52% to 14.28%, resulting in hardness values increasing from 245.50 g to 598.00 g. For both date and mango bars, total sugars (44.30–62.15%), starch digestibility (336.86–455.76%), water-holding capacity (0.6873% to 0.5077%) and brix values (47.35–71.98) varied significantly, while color values declined and microbial counts remained safe over storage. These results demonstrated that *quinoa*-enriched fruit bars maintain nutritional quality and consumer acceptability over 45 days, making them a promising functional snack.

Keywords: dates, fruit-based bars, functional foods, mango, physicochemical and microbial analysis

Introduction

Quinoa (*Chenopodium quinoa* Willd), an ancient pseudocereal native to the Andean region of South America, has gained widespread recognition for its exceptional nutritional profile and adaptability. Unlike traditional grains, *quinoa* is gluten-free and a complete protein source, containing all essential amino acids, making it particularly valuable for individuals seeking plant-based nutrition (Hernández-Ledesma, 2019; Villacrés *et al*., 2022). Additionally, *quinoa* is a rich source of dietary fiber, unsaturated fatty acids, vitamins, and minerals such as iron, zinc, and magnesium, contributing to its classification as a functional food (Dakhili *et al*., 2019; Angeli *et al*., 2020). *Quinoa*'s resilience to extreme environmental conditions, including drought and frost, underscores its potential as a sustainable crop for food security in regions facing climatic challenges. This ability to thrive in nutrient-poor soils further elevates its importance as a climate-resilient food source (Hussain *et al*., 2021; Melini & Melini, 2021). These attributes, combined with its high nutrient density, have made *quinoa* a preferred choice in the development of functional foods aimed at improving public health outcomes (Carrizo *et al*., 2020; Romano *et al*., 2020). *Quinoa*'s functional value is due to its rich bioactive compounds, including flavonoids, saponins, and phenolic acids, as those have demonstrated strong antioxidant, anti-inflammatory and beneficial effects on cardiovascular system (Dakhili *et al*., 2019; Hernández-Ledesma, 2019). Furthermore, *quinoa*'s unique starch profile, characterized by low amylose content and high digestibility, enhances its versatility in food product formulations (Pellegrini *et al*., 2018; Li & Zhu, 2018). As a result, *quinoa* has become a cornerstone ingredient in the development of functional food products.

Functional foods, which provide health benefits beyond basic nutrition, are increasingly popular among health-conscious consumers (Li *et al.,* 2025; Zhang *et al.,* 2024). *Quinoa*'s incorporation into products such as fruit bars has gained particular attention for its ability to enhance protein content, amino acid balance, and fiber levels (Carrizo *et al*., 2020; Romano *et al*., 2020). Additionally, *quinoa*'s low glycemic index and satiating properties make it an ideal component for on-the-go pseudocereals snacks designed for energy management and overall health improvement (Hernández-Ledesma, 2019; Villacrés *et al*., 2022). Fruits are considered a great source of phytochemicals, vitamins, and minerals. Remarkably, nutrients are concentrated and dispersed in fruit bars. Since fruit bars contain a mixture of fruits, they have a richer nutritional content than a single fruit (Gorsi *et al*., 2024; Aziz *et al.,* 2024; Wang *et al.,* 2022). The bars serve as a healthier source of essential nutrients having different taste which is ready to consume (Padmashree *et al*., 2018). Lifestyle changes and dietary behaviors, increased understanding of healthy eating habits with sufficient nutrient needs, and busy routine activities have made food bars a great choice for high-energy intake sources (Barakat & Alfheeaid, 2023; Altuncevahir *et al*., 2024). Mango is consumed for its high content of vitamin C, carotenoids, and dietary fiber, which contribute to its antioxidant properties and unique flavor (Pathan & Siddiqui, 2022; Hussain *et al*., 2024a). Dates, on the other hand, are a natural source of sugars, potassium, and polyphenols, enhancing the energy density and overall antioxidant capacity of functional fruit bars (Agarwal *et al*., 2023; Pellegrini *et al*., 2018).

Dates and mangoes together create a balanced, nutrient-dense snack that caters to modern dietary preferences for convenience and health (Maldonado-Celis *et al*., 2019; Hossain, 2019). The increasing popularity of *quinoa*-based products reflects broader trends in the food industry toward plant-based, sustainable, and functional foods. The integration of mango and dates with *quinoa* in fruit bars further enriches their nutritional value (Hussain *et al*., 2021). Products combining dates, mangoes, and *quinoa* are gaining popularity across diverse food categories due to their nutritional and functional benefits. For example, mango-based fruit bars, made from whole mango (peel and pulp), provide substantial dietary fiber and phenolic compounds, enhancing their nutritional and functional value (Shouket *et al.,* 2024). These bars also offer notable antioxidant capacity and potential physiological benefits, making them a natural and health-promoting snack option (Hernández-Maldonado *et al*., 2019). *Quinoa*-based gluten-free cakes, enriched with probiotics and protein, cater to dietary needs of health-conscious consumers while maintaining desirable sensory qualities (Amini *et al*., 2022). Additionally, date-enriched beverages, such as vitamin D-fortified milk, offer functional and appealing nutritional options for children (Jufri *et al*., 2023). Similarly, mango pulp addition in dairy beverage has also been made to get functional benefits (Siddique *et al*., 2024). Another innovative product line is fermented spoonable vegan products, made with *quinoa* flours blended with dates or other fruits, offering probiotic benefits and high nutritional value (Väkeväinen *et al*., 2020). Thus, fruit bars having *quinoa*, date, and mango in their recipe could offer valuable and diverse nutrient and bioactive compositions for health-conscious consumers; therefore, this work could prove beneficial for both consumers and food producers in order to have a new range of nutritional and functional food bars in the markets. This study focuses on the development, quality analysis, and nutritional evaluation of *quinoa*-based fruit bars enriched with mango and dates, aiming to create a product that offers exceptional health benefits while meeting sensory expectations. Additionally, it seeks to evaluate shelf life under varying storage conditions.

Materials and Methods

Procurement of raw material

This work was carried out during November 2023 to January 2024, at Muhammad Nawaz Shareef University of Agriculture, Multan, Pakistan. All plant materials utilized in this study are cultivated species; thus, no special permission was needed for their use. Nonetheless, their handling complied with all relevant national and international guidelines and standards. *Quinoa* (Chenopodium quinoa Willd.), a pseudocereal rich in high-quality protein, dietary fiber, and essential minerals, was obtained from the Agronomy Department of Muhammad Nawaz Shareef University of Agriculture, Multan, and used for the development of the functional product. Mango (*Mangifera indica* L.) was also procured from the local market, and pulp was prepared using a mixer (PS, 2944, Panasonic, Japan). Similarly, date (*Phoenix dactylifera* L.) was also obtained from the local market, and pulp was prepared manually. All chemicals required for the analysis were sourced from the local market in Multan. Each analysis was performed in triplicate to determine the mean values.

Proximate analysis

Prior to analysis, the *quinoa* sample was washed thoroughly with distilled water to remove the saponin layer responsible for bitterness. The cleaned *quinoa* was then dried at 105°C for 24 hours in a hot air oven (HAT, 110, Biobase, China) until constant weight was achieved and subsequently ground into powder using a crushing machine (Model CM-200, Panasonic, Japan). Proximate analysis of *quinoa*, mango, and date samples was conducted following AOAC protocols. Moisture content was determined using the oven-drying method in a hot air oven (HAT, 110, Eco Star, Pakistan) at 105°C for 24 hours (AOAC, 2000). Crude protein content was analyzed using Kjeldahl's method with a Kjeldahl apparatus (Model KDN-08, locally available in Pakistan) (AOAC, 2000). Crude fat was measured through Soxhlet extraction using a Soxhlet apparatus (Model E-816, locally fabricated in Pakistan) (AOAC, 2000). Ash content was determined by incineration in a muffle furnace (MF-300, Pak Lab Industries, Pakistan) at 550°C (AOAC, 2000). Crude fiber content was analyzed using a fiber analyzer (Fiber Tech, Model FI-12, locally available in Pakistan) (AOAC, 2000).

Mineral analysis of raw materials

Calcium, sodium, and potassium content in *quinoa*, mango, and date samples were analyzed using a flame photometer (Model FP-410, Sherwood Scientific, UK). The analysis was conducted following standard protocols (AOAC, 2000).

Preparation of fruit bars

For development of food bars, the research work was performed in the Laboratory of the Department of Food Science and Technology at Muhammad Nawaz Shareef University of Agriculture, Multan. Fruit bars were prepared following the standard protocol described by Padmashree *et al.* (2018), with minor modifications. Dry ingredients were thoroughly mixed using a mixer (Model PS-2944, Panasonic, Japan), and fruit pulp was gradually incorporated. The mixture was then kneaded manually with clean, sanitized hands and shaped into bars using a rectangular mold. The detailed treatment plan is illustrated in Table 1.

Proximate analysis of fruit bars

Proximate analysis of fruit bars (*quinoa* date bar and *quinoa* mango bar) was conducted following AOAC protocols (AOAC, 2000). Moisture content was determined using the oven-drying method in a hot air oven (HAT, 110, EcoStar, Pakistan) at 105°C for 24 hours (AOAC, 2000). Crude protein content was analyzed by Kjeldahl's method using a Kjeldahl apparatus (Model KDN-08, locally available in Pakistan) (AOAC, 2000). Crude fat content was measured via Soxhlet extraction using a Soxhlet apparatus (Model E-816, locally fabricated in Pakistan) (AOAC, 2000). Ash content was determined by incineration in a muffle furnace (MF-300, Pak Lab Industries, Pakistan) at 550°C (AOAC, 2000). Crude fiber content was analyzed using the standard method with a fiber analyzer (Fiber Tech, Model FI-12, locally available in Pakistan) (AOAC, 2000).

Table 1. Treatment plan for fruit bars (percentage of quinoa flour in date and mango bars).

Treatments Code	Description	Quinoa (g)
Cd	Control (Date Bar)	0
Cm	Control (Mango Bar)	0
D1	10% Quinoa flour (Date Bar)	10
D2	20% Quinoa flour (Date Bar)	20
D3	30% Quinoa flour (Date Bar)	30
M1	10% Quinoa flour (Mango Bar)	10
M2	20% Quinoa flour (Mango Bar)	20
M3	30% Quinoa flour (Mango Bar)	30

Chemical analysis

Mineral analysis of fruit bars

Calcium, sodium, and potassium content in bars made with *quinoa*, mango, and date samples was analyzed using a flame photometer (Model FP-410, Sherwood Scientific, UK). The analysis was conducted following standard protocols (AOAC, 2000).

Total sugars, reducing sugars and non-reducing of fruit bars

Total sugars, including reducing and non-reducing sugars, present in fruit bars were calculated according to standard protocols by the titration method using Fehling solution (AOAC, 2000).

Titratable acidity

Titratable acidity of fruit bars was determined by acid titration method according to the standard protocols using 0.1 N NaOH standard solution (AOAC, 2000).

Determination of pH

The pH of fruit bars was determined by using pH meter (Model PH-209B by Lutron) according to the standard protocols (AOAC, 2000).

Calorific value

Calorific value of fruit bars was determined according to standard protocol using factors of 3.75, 3.75, and 9.0 kcal/g for carbohydrate, protein, and lipid, respectively. All energy contents were summed to obtain the total calorific value of *quinoa* bars (Munir *et al*., 2018).

In-vitro starch digestibility

In vitro starch digestibility of fruit bars was determined according to the standard protocols adopted by Chau and Cheung (1997).

Water holding capacity

Water holding capacity of fruit bars was determined according to the standard protocol used by Mahnoor *et al*. (2024).

Physical analysis

Texture analysis

Texture of fruit bars was analyzed using a texture analyzer (TA.XT Plus, Stable Micro Systems, UK) according to the standard protocol used by Din *et al*. (2024), to determine hardness and fracturability.

Color determination

Color of fruit bars was analyzed according to the standard protocol adopted by Hussain *et al*. (2023), with some modifications, using a colorimeter (CFEZ0385, USA). Colorimeter readings (L*, a*, b*) were recorded and compared with standards to obtain actual results.

Brix content determination

Brix of fruit bars was analyzed using a hand refractometer (RHB-32ATC) with a 0–32 brix range, according to the standard protocol used by Siddique *et al*. (2024).

Microbiological analysis

Microbiological analysis of fruit bars, including total plate count and mold/yeast count, was carried out using the standard dilution method provided by Christen and Parker (2020), and validated through microbial inactivation assessments (Garre *et al*., 2019).

Sensory analysis

Sensory evaluation of fruit bars was performed at Department of Food Science and Technology, Muhammad Nawaz Shareef University of Agriculture, Multan, Pakistan, with the help of teachers and students to assess the acceptability of fruit bars based on color, flavor, taste, texture, and overall acceptability using a 0–9 hedonic scale, as done by Arinzechukwu and Nkama (2019). Briefly, an untrained panel of 35 evaluators (volunteers from the department where trials were performed), comprising both genders and with an average age between 25 and 35 years, participated in the sensory evaluation. These participants were involved in the study from December 1, 2023, to January 30, 2024, when the final product was ready for assessment. The study did not include minors. Informed verbal consent was obtained from all participants and recorded for documentation.

Statistical analysis

The obtained data were evaluated to determine the acceptability and quality of fruit bars through statistical analysis using a two-factorial Completely Randomized Design (CRD) and Analysis of Variance (ANOVA) techniques, with a significance level of $p \leq 0.05$(Aslam *et al*., 2023).

Results and Discussion

Proximate analysis of raw material

The results presented in Table 2 show that quinoa has the highest protein content, while mango has the lowest protein content. Table 2 presents the results, showing that quinoa also has the highest fiber content, while mango has the lowest fiber content. In terms of fat content, quinoa has the highest fat percentage, whereas both date and mango have the lowest fat contents. The moisture

Table 2. Proximate analysis of quinoa, date and mango.

Parameter	Quinoa	Date	Mango
Moisture (%)	8.9±0.04[c]	18.15±0.6[b]	82.5±0.15[a]
Protein (%)	16.05±0.05[a]	3.28±0.02[b]	1.09±0.03[c]
Fat (%)	5.8±0.04[a]	0.55±0.03[b]	0.49±0.02[c]
Fiber (%)	9.76±0.06[a]	2.27±0.04[b]	1.26±0.02[c]
Ash (%)	3.36±0.02[b]	5.96±0.04[a]	0.55±0.01[c]

Values in a column with similar letters are non-significant, whereas values with different letters are significant (p ≤ 0.05).

Table 3. Mineral analysis of quinoa, date and mango.

Parameter	Quinoa	Date	Mango
Sodium (mg/100g)	3.4±0.05[b]	4.48±0.02[a]	2.4±0.02[c]
Potassium (mg/100g)	730±0.40[b]	844±0.20[a]	202±0.10[c]
Calcium (mg/100g)	72±0.05[b]	146.30±0.08[a]	16±0.03[c]

Values in a column with similar letters are non-significant, whereas values with different letters are significant (p ≤ 0.05).

content is highest in mango, followed by date, with quinoa having the lowest moisture content. In terms of ash content, date has the highest ash content, while mango has the lowest ash content. Our findings are in accordance with recent studies that highlight quinoa's superior nutritional composition compared to other plant and fruit sources. Quinoa's high protein content and essential amino acid profile, as documented, underscore its potential as a complete protein source (Gómez *et al.*, 2021). Additionally, the rich fiber content in quinoa is consistent with prior evaluations demonstrating its contribution to gut health and its classification as a high-fiber pseudocereal (Campos-Rodriguez *et al.*, 2022). Furthermore, the elevated ash content in dates agrees with findings that study dates as a rich source of minerals, including calcium and magnesium (Odunayo *et al.*, 2022). Similarly, the results of the chemical composition of mango pulp reported here are in line with the previous findings of Hussain *et al.* (2024a) and Hussain *et al.* (2024b), as the authors also reported a similar amount of ash, fiber, and protein in mango pulp. Thus, from this chemical composition of raw materials analyzed, it could be considered that quinoa, due to its diverse composition, could contribute these nutritional contents to the food products in which it is added.

Mineral analysis of raw material

The result presented in Table 3 shows that date has the highest sodium content, while mango has the lowest sodium content. The data given in Table 3 also indicates that date also has the highest potassium content, while mango has the lowest potassium content. In terms of calcium content, date has the highest value, while mango has the lowest calcium content. Our results align with previous studies that emphasize the superior mineral content in dates compared to other plant-based foods. Dates were identified as a rich source of potassium and calcium, critical for maintaining heart health and bone strength (Salomón-Torres *et al.*, 2019). Similarly, quinoa's relatively high potassium and calcium levels support its reputation as a nutrient-dense pseudocereal beneficial for various health conditions, as corroborated by other recent analyses (Rodríguez Gómez *et al.*, 2021). Meanwhile, mango's lower mineral content is consistent with its classification as a hydrating fruit rather than a concentrated mineral source (Shaikh *et al.*, 2021). The mineral composition of the mango pulp reported here is also consistent with the findings of Hussain *et al.* (2024a) and Hussain *et al.* (2024b), who also reported a comparable level of calcium, potassium, and sodium in the pulp. Because of their varied mineral compositions, it is possible to infer from the chemical composition of the raw materials that all three of them could give these mineral contents to the snack bars to which they are added.

Proximate analysis of fruit bars

For proximate analysis of fruit bars, the results presented in Figures 1–5 show that moisture content had non-significant ($p < 0.01$) interactions during days but showed a significant ($p < 0.01$) effect for treatments. Moisture content ranged from 17.988% (Cd) to 14.258% (D3), with a maximum of 18.253% (Cd, day 15) and a minimum of 14.130% (D3, day 45). The data presented in Figure 2 reveal that ash content showed no significant ($p < 0.01$) interactions during days but showed significant ($p < 0.01$) effects for treatments. Ash content ranged from 4.6258% (D3) to 2.1650% (Cd), with a maximum of 4.6867% (D3, day 0) and a minimum of 2.0767% (Cd, day 45). The data given in Figure 3 show that crude fat content had significant ($p < 0.01$) interactions and treatment effects. Fat content ranged from 7.0883% (D3) to 0.9550% (M2), with a maximum of 7.1333% (D3, day 0) and a minimum of 0.9400% (M2, day 45). Similarly, Figure 4 presents results showing that crude protein content exhibited no significant ($p < 0.01$) interactions but demonstrated significant treatment effects on fruit bars. Protein content ranged from 14.437% (D3) to 8.893% (Cm), with a maximum of 14.514% (D3, day 0) and a minimum of 8.880% (Cm, day 15). The data presented in Figure 5 show that crude fiber content had significant ($p < 0.01$) interactions and treatment effects. Fiber content ranged from 6.8883% (D3) to 3.5500% (Cd), with a maximum of 6.9533% (D3, day 0) and a minimum of 2.0000% (Cm, day 45). The results presented in Figure 6 indicate that NFE content had

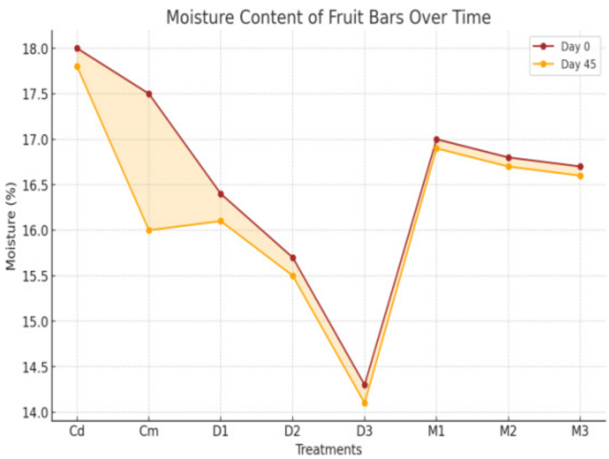

Figure 1. **Results of moisture content of fruit bars.**

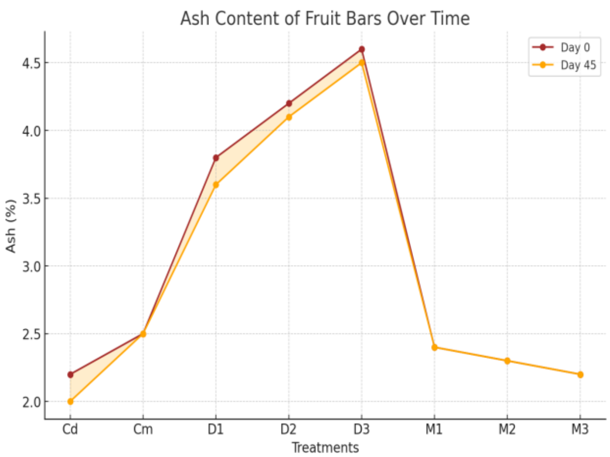

Figure 2. **Results of ash content of fruit bars.**

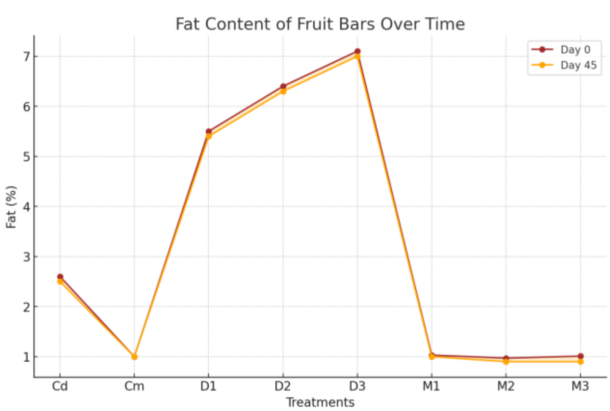

Figure 3. **Results of fat content of fruit bars.**

Figure 4. **Results of protein content of fruit bars.**

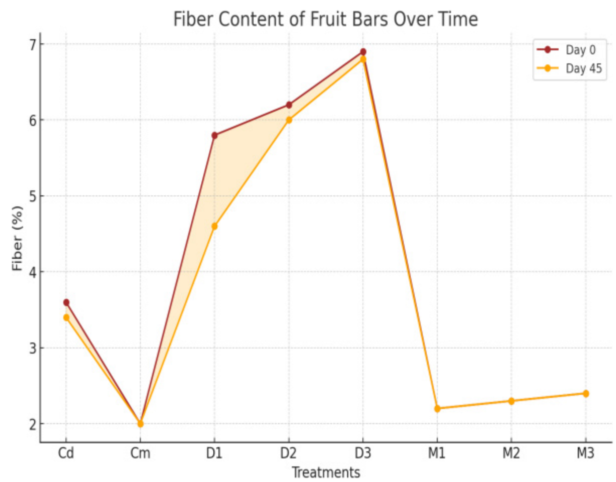

Figure 5. **Results of fiber content of fruit bars.**

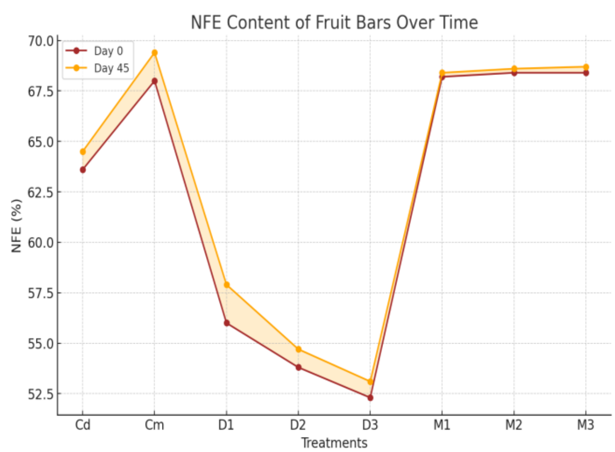

Figure 6. **Results of NFE content of fruit bars.**

significant ($p < 0.01$) interactions and treatment effects. The NFE content decreased for most treatments from day 0 to day 45, with a sharp increase observed in M1, M2, and M3 by day 45. Our findings on the proximate analysis of fruit bars revealed significant effects of treatments on moisture, protein, fat, fiber, ash, and NFE content, while interactions over days were generally non-significant. A similar chemical composition of energy bars developed from quinoa and other ingredients has also been reported by Kaur *et al*. (2018). These results align with findings demonstrating that the nutritional composition of fruit- and vegetable-based products varies significantly depending on the treatment methods and composition of raw materials (Kamau *et al.*, 2020). The crude protein and ash content variations observed in our study are comparable to reports highlighting the impact of processing on protein and mineral retention in fruit-based products (Umar *et al.*, 2021). Furthermore, the variations in fiber and carbohydrate levels are consistent with findings showing that blending ratios and processing techniques significantly influence these parameters in fruit-based products (Arinzechukwu & Nkama, 2019). The use of pseudocereals in the fruit bars has been found increasingly beneficial due to the high amount of ash, fiber, and protein contents in these crops (Sabeel *et al.*, 2024).

Chemical Analysis

Mineral analysis of fruit bars

Fruit bars having cereals and pseudocereals could be a good source of macro minerals (Kaur *et al.*, 2018). For mineral analysis, the results presented in Figure 7 show that sodium content in fruit bars had non-significant ($p < 0.01$) interactions during days and treatments, with values ranging from 422.79 mg/100g (Cd) to 277.14 mg/100g (M1). The maximum value was 293.40 mg/100g (D3, day 0), and the minimum was 242.25 mg/100g (Cm, day 45). Further, the data presented in Figure 8 show that potassium content in fruit bars exhibited significant ($p < 0.01$) interactions during days and treatments, ranging from 625.90 mg/100g (D3) to 584.12 mg/100g (Cm). The highest value was 628.87 mg/100g (D3, day 0), and the lowest was 508.78 mg/100g (D2, day 45). Moreover, the data given in Figure 9 show that calcium content in fruit bars had non-significant ($p < 0.01$) interactions during days and treatments, with values ranging from 213.72 mg/100g (Cd) to 144.03 mg/100g (M1). The maximum value was 462.68 mg/100g (Cd, day 30), and the minimum was 127.50 mg/100g (Cm, day 45). Our findings were in accordance with studies showing that sodium

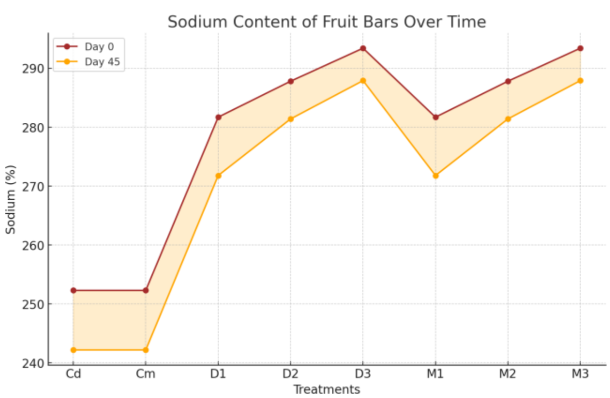

Figure 7. Results of sodium content of fruit bars.

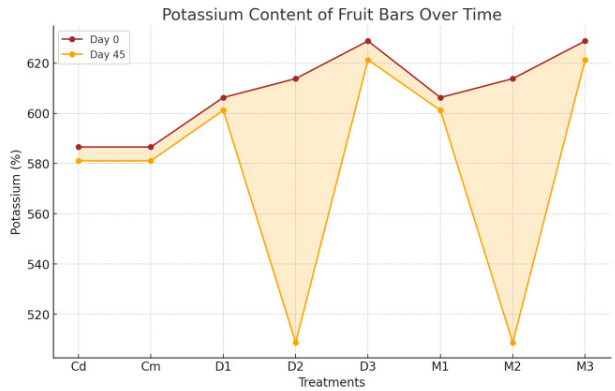

Figure 8. Results of potassium content of fruit bars.

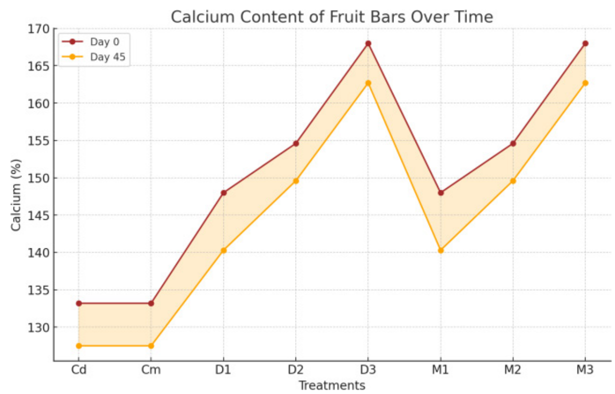

Figure 9. Results of calcium content of fruit bars.

levels in fruit-based products are minimally influenced by treatment variations but slightly affected by preparation methods (Pertiwi *et al.*, 2022). Our analysis was very comparable with research demonstrating that potassium plays a crucial role in determining nutrient composition and quality, significantly influenced by treatments (Sahu *et al.*, 2023). Additionally, our results were in line with findings highlighting that calcium content remains stable across treatments and contributes to the structural integrity of fruit-based products (Czech *et al.*, 2020). Because pseudocereals contain a lot of minerals, their usage in fruit bars has been shown to be increasingly advantageous. Pseudocereals are high in vital minerals and have been validated for their ability to promote health, making them appropriate for people with mineral deficiencies (Sabeel *et al.*, 2024).

Total sugars, reducing sugars and non-reducing sugars

The sugar contents and variations in the total, reducing, and non-reducing sugars depend upon the ingredients and raw materials used in the development of food bars (Kaur *et al.*, 2018). The result presented in Figure 10 shows that total sugars in fruit bars exhibited a highly significant ($p < 0.01$) interaction during days and treatments. The combined effect of treatment and days was

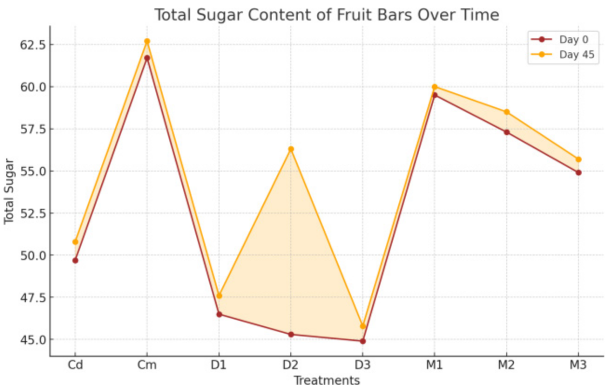

Figure 10. **Results of total sugars of fruit bars.**

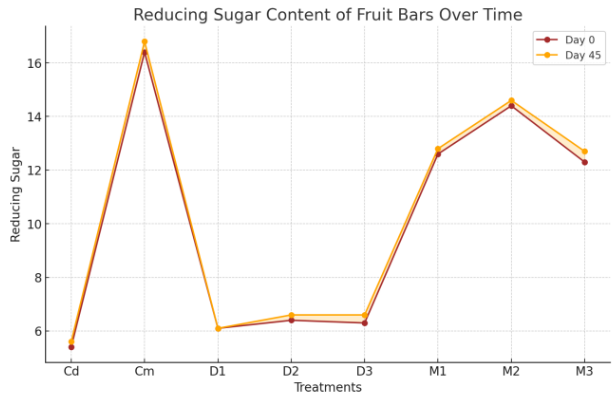

Figure 11. **Results of reducing sugars of fruit bars.**

non-significant ($p < 0.05$). Total sugars ranged from 62.150% (Cm) to 45.300% (D3). The maximum value was 62.700% (Cm, day 45), and the minimum was 44.900% (D3, day 0). These findings highlight significant differences based on treatments and storage duration. Data in Figure 11 depicts that reducing sugar contents ranged from 6.0% (Cd) to 16.0% (Cm) across treatments, with a significant increase noted in M1, M2, and M3 by day 45. Moreover, it can be examined from Figure 12 that non-reducing sugar content ranged from 40.0% (D3) to 46.0% (Cm), with day 45 depicting elevation for most treatments, particularly in M1, M2, and M3. The results of this study align with previous findings that total sugar content in fruit bars significantly varies depending on treatment methods and ingredient composition, with minimal interaction effects over storage time (Munir *et al*., 2018). These findings also correspond with evidence that sugar levels in fruit-based products are influenced by blending ratios and processing techniques, which contribute to the stability and nutritional value of the bars (Eyiz *et al*., 2020). Furthermore, the impact of sugar content on sensory properties and consumer acceptability reinforces the importance of optimizing sugar levels for producing high-quality fruit bars (Srivastava *et al*., 2019).

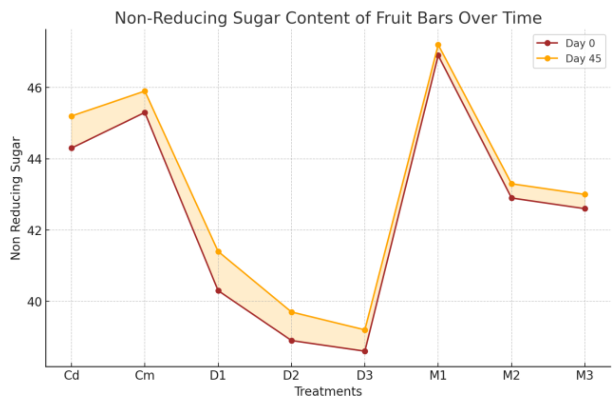

Figure 12. **Results of non-reducing sugars of fruit bars.**

Titratable acidity

The data given in Figure 13 show that titratable acidity in fruit bars had a non-significant ($p < 0.01$) interaction during days but exhibited a highly significant ($p < 0.01$) impact during treatments. The data given in Figure 13 indicate that titratable acidity ranged from 0.5750% (M3) to 0.3283% (Cd). The maximum value recorded was 0.5900% (M1, day 45), while the minimum was 0.3167% (Cd, day 45). These results highlight the significant effect of treatments on acidity levels in fruit bars. Our findings were in line with studies that reported the significant impact of treatments on titratable acidity in fruit-based products, demonstrating that treatments influence acidity levels while storage duration has a lesser effect (Yulistiani *et al*., 2022). The results were also comparable

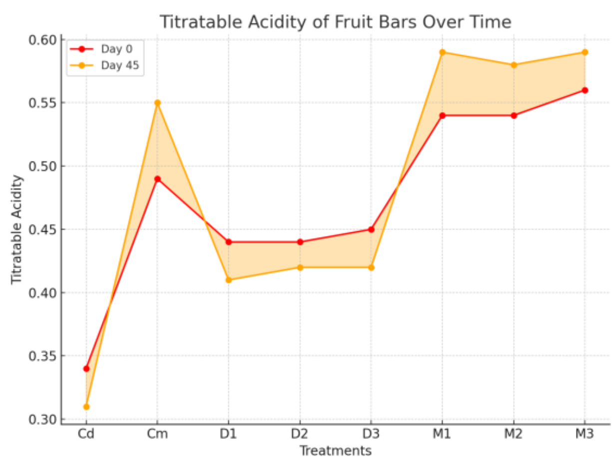

Figure 13. **Results of titratable acidity of fruit bars.**

with research showing that the use of specific acidulants and processing methods significantly affect acidity and other chemical properties of fruit products (Tsegay, 2020). Additionally, our findings were consistent with studies emphasizing that variations in acidity contribute to the sensory attributes and overall quality of fruit-based bars (Gahane *et al*., 2024). This variation in the titratable acidity of the bar treatments could be attributed towards high acidity of mango pulp as compared to the date fruit, which might have contributed towards the rise in the acidity (Siddique *et al.*, 2024).

Determination of pH

The result explained in Figure 14 shows that the pH of fruit bars had a non-significant ($p < 0.01$) interaction during days but exhibited a highly significant ($p < 0.01$) impact during treatments. The data given in Figure 14 depict that pH values ranged from 5.9050 (Cd) to 4.2150 (M3). The maximum pH noted was 5.9200 (Cd, day 0), while the minimum was 4.2000 (M3, day 45). These findings suggest that treatments significantly affected the pH levels in fruit bars. Our results were in accordance with findings that treatments significantly influence pH levels in fruit-based products, while the impact of storage time remains minimal (Eyiz *et al.*, 2020). Our analysis was very much comparable with studies highlighting that pH adjustments during processing can enhance the sensory and shelf-stability characteristics of fruit bars (Hanum *et al.*, 2022). Additionally, our results were in line with research showing that pH stability is a crucial factor for maintaining the chemical integrity of fruit-based products during storage and handling (Gireesh *et al.*, 2022). As mango and date have different pH values, which are also different from quinoa, the different variations of these ingredients are responsible for the variations in the pH of the bars.

Calorific value

The result presented in Figure 15 demonstrates that the calorific value of fruit bars showed a significant ($p < 0.01$) interaction across days and a highly significant ($p < 0.01$) effect across treatments. The data given in Figure 15 indicate that calorific values ranged between 316.41 kcal (D3) and 297.90 kcal (Cm). The mean values for treatments were between 315.57 kcal (D3) and 299.10 kcal (M1), while the mean values for days ranged from 303.29 kcal (day 0) to 305.34 kcal (day 45). The highest calorific value was 316.41 kcal (D3, day 45), and the lowest was 297.90 kcal (Cm, day 0). The bars having date as their ingredient have shown high calorific values, which are found to further increase as a result of higher levels of quinoa; these are possibly due to the high carbohydrates in these ingredients. Our findings were in accordance with studies showing that the calorific value of fruit bars is significantly influenced by treatments, with changes reflecting variations in the nutritional composition of the ingredients used (Munir *et al.*, 2018). The results are comparable with research highlighting the importance of processing methods and ingredient composition in determining the calorific value of snack bars, which can significantly vary based on treatment combinations (Saletnik *et al.*, 2021). Additionally, the data align with studies emphasizing that the calorific content of fruit bars is a critical factor for energy-dense snacks, ensuring product acceptance and consumer satisfaction (Eyiz *et al.*, 2020).

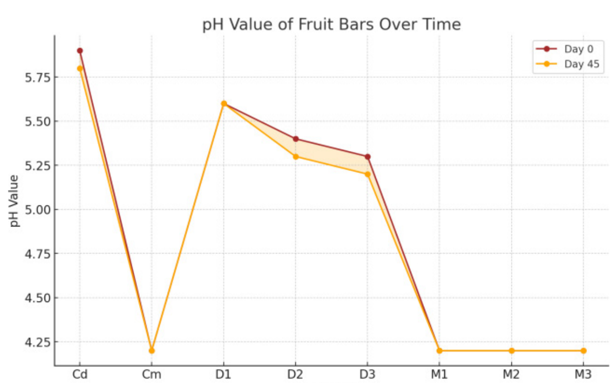

Figure 14. Results of pH value of fruit bars.

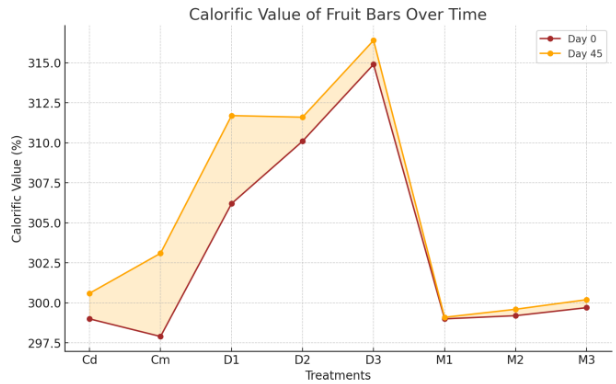

Figure 15. Results of calorific value of fruit bars.

In-vitro starch digestibility

Figure 16 depicts that in-vitro starch digestibility of fruit bars had a non-significant ($p < 0.01$) interaction over the days but displayed a highly significant ($p < 0.01$) effect for treatments. The data presented in Figure 16 reveal that digestibility values varied between 455.76% (M3) and 336.86% (Cd). The mean values for days ranged from 399.14% (day 0) to 393.04% (day 45). The highest digestibility observed was 456.00% (M3, day 0), and the lowest was 321.64% (D1, day 45). The results were consistent with studies showing that treatment variations significantly influence in-vitro starch digestibility in fruit-based products due to structural modifications in the starch matrix (Zhang *et al.*, 2019). These findings support evidence that heat and moisture-based processing techniques enhance enzymatic digestibility by altering starch crystallinity and molecular arrangement (Yan *et al.*, 2020). Furthermore, the relationship between processing-induced changes in starch structure and improved digestibility aligns with prior research emphasizing the importance of functional modifications in optimizing the nutritional quality of fruit-based products (Zhou *et al.*, 2020).

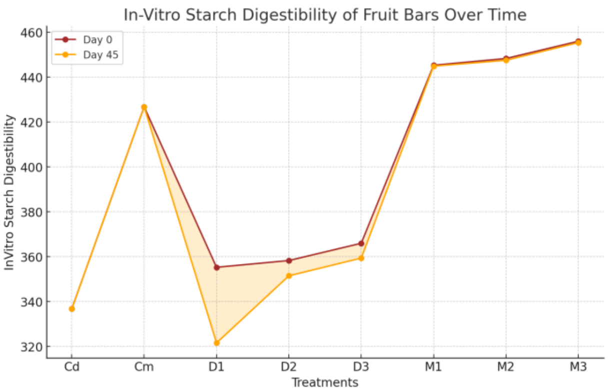

Figure 16. Results of in-vitro starch digestibility of fruit bars.

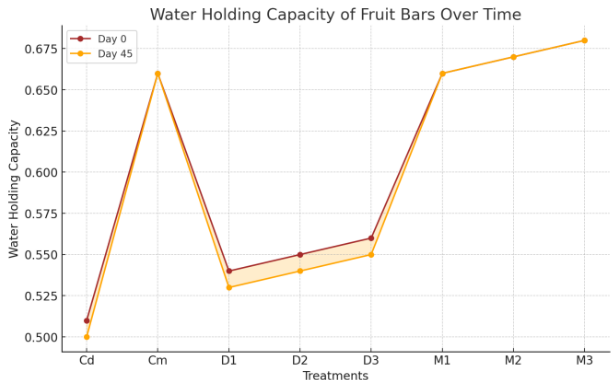

Figure 17. Results of water holding capacity of fruit bars.

Water holding capacity

Figure 17 reveals that the water holding capacity of fruit bars was significantly ($p < 0.01$) influenced by treatments, while interactions across days remained non-significant ($p < 0.01$). Notably, the water holding capacity varied across treatments, with values ranging from 0.6873% for M3 to 0.5077% for Cd. Across days, the mean values slightly fluctuated between 0.6085% (day 0) and 0.6043% (day 45). The highest water holding capacity, 0.6890%, was observed in M3 on day 45, while the lowest, 0.5080%, occurred in Cd on day 15. Our findings were in line with research emphasizing that water holding capacity in fruit-based products is significantly influenced by treatments due to modifications in structural composition, while storage duration has minimal impact (Ozilgen, 2011). The results were comparable with studies that demonstrated the role of enzymatic and compositional changes in enhancing water retention properties, crucial for the textural and sensory quality of fruit bars (Canela-Xandri *et al.*, 2018). Additionally, our analysis aligned with findings highlighting that coating and processing methods can optimize water activity and moisture retention in fruit-based snacks, contributing to prolonged shelf life and consumer acceptance (Eyiz *et al.*, 2020). These higher water holding capacities of mango and quinoa-based bars could be attributed towards the high fiber contents in the mango and quinoa (Sabeel *et al.*, 2024; Kaur *et al.*, 2018).

Physical analysis

Texture analysis

The data in Figure 18 illustrates a highly significant ($p < 0.01$) effect of treatments and days on the hardness of fruit bars, while the combined effect of treatment and days was non-significant ($p < 0.05$). Treatment values ranged from 627.50 (M3) to 241.30 (D_2), showing considerable variation. Day-based means were 462.64 (day 0) and 477.68 (day 45), indicating a slight increase over time. The maximum recorded hardness was 635.00 (M3, day 45), while the minimum was 233.77 (D_2, day 0). As presented in Figure 19, treatments had a highly significant ($p < 0.01$) effect on the fracturability of fruit bars, while interactions over days and the combined influence of treatments and days were non-significant ($p < 0.05$). Fracturability values varied from 72.790 (D_2) to 32.871 (M3) across treatments. The day-based means were nearly stable, with 52.542 recorded at day 0 and 52.419 at day 45. The highest value, 72.820, was observed in D_2 on day 0, while the lowest, 32.740, was recorded in M3 on day 45. The high hardness of mango bars having higher levels of quinoa might be due to the hard texture of these bars resulting from the high quinoa starch presence, while date bars, due to more water absorption, have shown low hardness values. The results confirm that treatments play a crucial role in determining the hardness and fracturability of fruit bars, as significant changes were observed across treatment variations (Eyiz *et al.*, 2020). This study further supports findings that structural integrity, particularly hardness, can be improved through optimized processing techniques and ingredient modifications (Munir *et al.*, 2018). Moreover, the observed variations in fracturability align with research showing

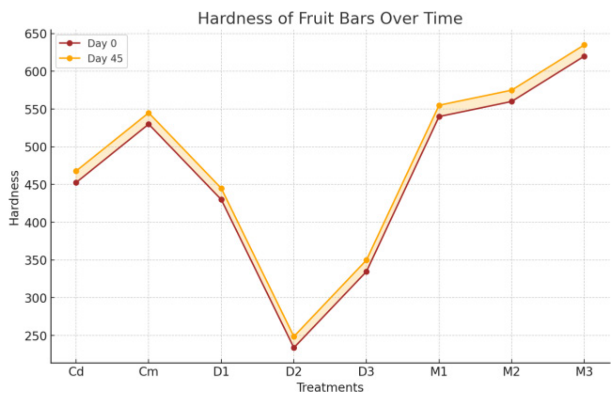

Figure 18. Results of hardness of fruit bars.

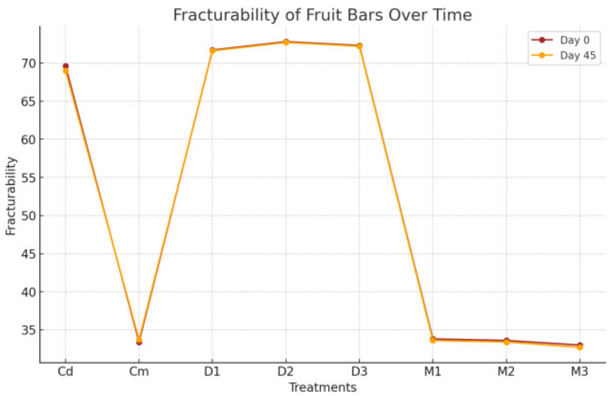

Figure 19. Results of fracturability of fruit bars.

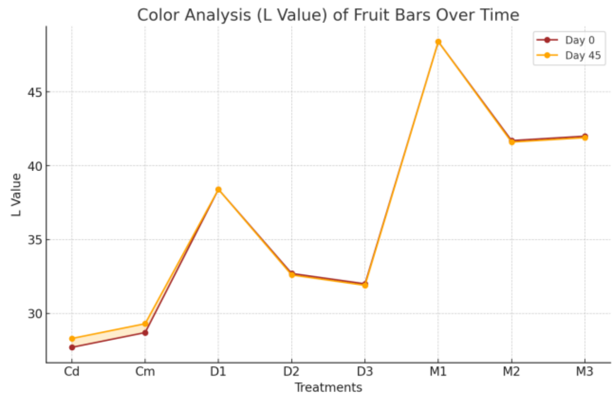

Figure 20. Results of color (L*) value of fruit bars.

that moisture content and protein interactions greatly influence textural stability and consumer acceptability (Ud Din *et al.,* 2025; Kigozi *et al.*, 2024). The variations of other ingredients like fat, fiber, and carbohydrates might also have contributed to the differences in hardness and fracturability of these bar treatments.

Color determination

Figures 20, 21, and 22 respectively reveal that the treatments significantly ($p < 0.01$) influenced the 'L', 'a', and 'b' color values of fruit bars, while interactions across days were non-significant ($p < 0.01$). However, the combined effect of treatments and days was highly significant ($p < 0.05$). The 'L' value ranged from 48.450 (M1) to 28.000 (Cd), the 'a' value from 18.605 (D_1) to 4.732 (Cd), and the 'b' value from 12.500 (M2) to 7.570 (D_1). Across days, mean values for 'L', 'a', and 'b' decreased slightly, with 'L' reducing from 36.485 (day 0) to 16.246 (day 45), 'a' from 9.2100 (day 0) to 9.1575 (day 45), and 'b' from 9.6450 (day 0) to 9.4375 (day 45). The maximum values recorded were 48.480 ('L', M1, day 0), 18.630 ('a', D_1, day 0), and 12.800 ('b', M2, day 0), while the minimum values were 27.700 ('L', Cd, day 45), 4.710 ('a', Cd, day 45), and 7.520 ('b', D_1, day 45). The results are consistent with research showing that treatments significantly influence the L*, a*, and b* color values of fruit-based products, highlighting the importance of ingredient composition and processing techniques in enhancing visual appeal (Eyiz *et al.*, 2020). These findings align with studies that demonstrate how color parameters are crucial for consumer acceptance, as they are directly linked to perceived quality and freshness (Manasa *et al.*, 2020). Moreover, our results complement evidence suggesting that controlled treatments can stabilize color properties over time, ensuring consistency and prolonged shelf life in fruit products (Aghajanzadeh *et al.*, 2023). The bars having low levels of quinoa and high levels of date and mango showed higher a* and b* values, while lower L* values, possibly due to the high pigments in mango and date compared to quinoa (Kaur *et al.*, 2018; Hussain *et al.*, 2024b).

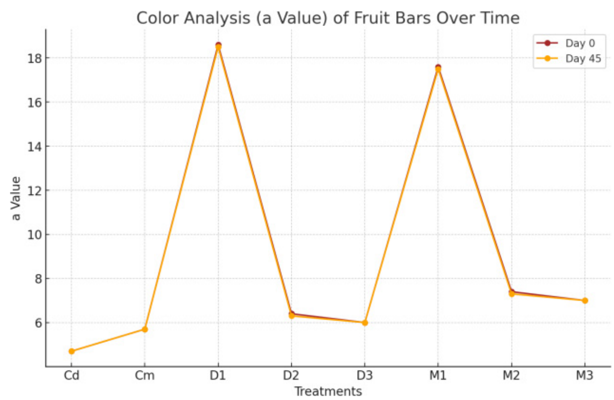

Figure 21. Results of color (a*) value of fruit bars.

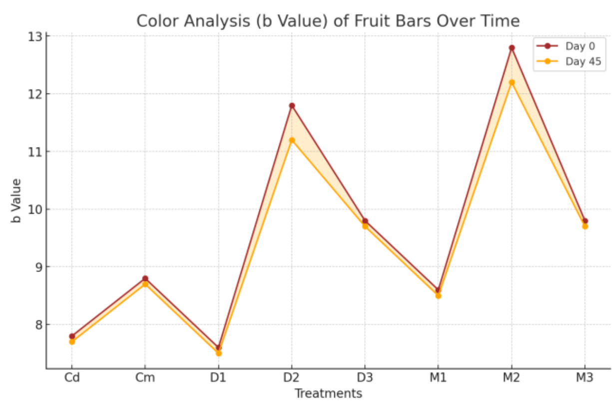

Figure 22. Results of color (b*) value of fruit bars.

Brix content

Data in Figure 23 highlights that the Brix content of fruit bars was significantly ($p < 0.01$) affected by treatments and days, while their combined interaction was not statistically significant ($p < 0.05$). The Brix content varied across treatments, ranging from 71.975 (M3) to 47.350 (D3). Mean values across days showed minimal differences, with 62.654 on day 0 and 63.250 on day 45.

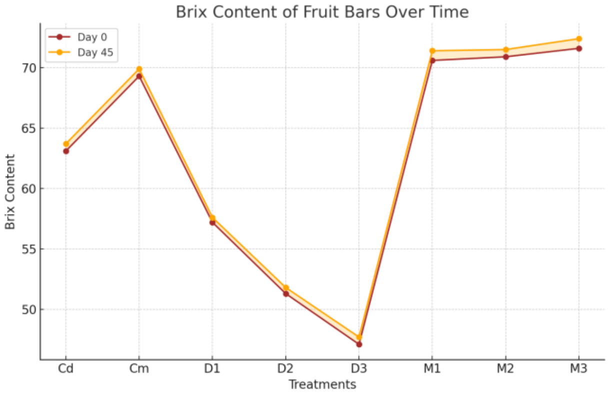

Figure 23. Results of brix content of fruit bars.

The highest Brix content, 72.400, was observed in M3 on day 45, while the lowest, 47.100, was recorded in D3 on day 0. These results indicate that treatments had a pronounced effect on Brix content, with storage time contributing less variability. The findings are consistent with studies highlighting the significant influence of treatments on Brix content in fruit bars, emphasizing that ingredient composition and processing methods play a pivotal role in regulating sweetness levels (Eyiz *et al*., 2020). These results also align with research demonstrating that Brix levels are crucial for consumer acceptance, as they determine the perceived quality and flavor of fruit-based products (Aslam *et al*., 2023). Furthermore, our results support evidence that storage duration has a relatively minor effect on Brix content compared to the significant impact of treatments, which ensure consistency and enhance product stability (Arinzechukwu & Nkama, 2019). The similar sugar contents of quinoa and mango may be responsible for the small variations in the Brix of mango-quinoa bars, whereas the larger differences in sugar content between date and quinoa likely account for the significant variation in the Brix of date bars containing different levels of quinoa.

Microbiological analysis

The results presented in Figure 24 show that the total plate count and mold count of fruit bars were significantly ($p < 0.01$) affected by both treatments and storage days, with a highly significant ($p < 0.05$) combined effect. The total plate count ranged from 2.7897 CFU/g (M2) to 1.5750 CFU/g (Cd), while mold count ranged from 2.7975 CFU/g (M3) to 1.4975 CFU/g (Cd). The highest values recorded were 2.9600 CFU/g for total plate count (M2, day 45) and 2.0000 CFU/g for mold count (M3, day 45), whereas the lowest counts were 1.2300 CFU/g (Cd, day 0) and 1.2060 CFU/g (D1, day 0), respectively. Our findings are consistent with previous studies indicating that microbial loads, including total plate and mold counts, are significantly influenced by treatments and storage duration in fruit-based products, underscoring the importance of effective processing techniques for ensuring microbial safety (Arinzechukwu & Nkama, 2019). These results align with research demonstrating that appropriate treatments can significantly reduce microbial growth while maintaining sensory quality, thereby extending shelf life (Eyiz *et al*., 2020). Furthermore, the data highlight that combining suitable ingredient formulations with optimized storage conditions can minimize microbial contamination, enhancing the overall safety and quality of fruit-based snacks (Rasouli *et al*., 2019). The antimicrobial properties of quinoa may explain the lower total plate and mold counts observed in bars with higher quinoa content (Dev and Gupta, 2024). Additionally, bioactive compounds present in mango pulp likely contributed to the reduced microbial counts in these bars (Hussain *et al*., 2024a).

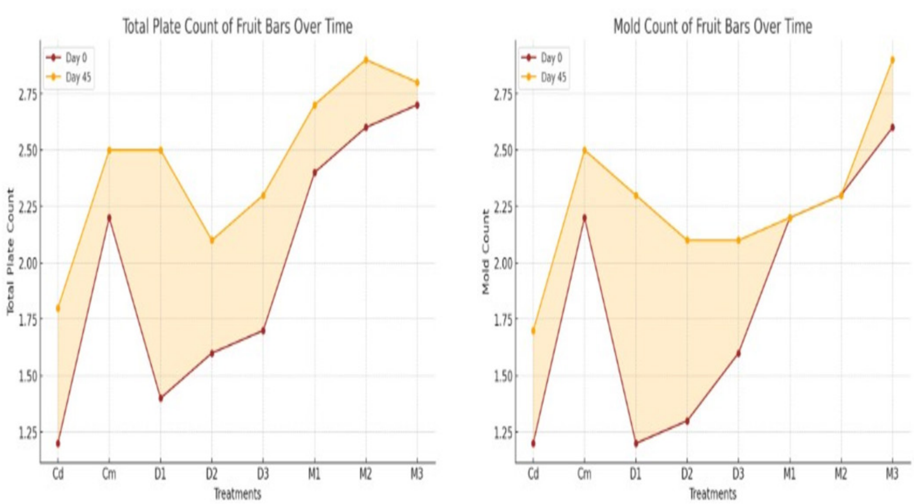

Figure 24. Results of total plate count and mold count of fruit bars.

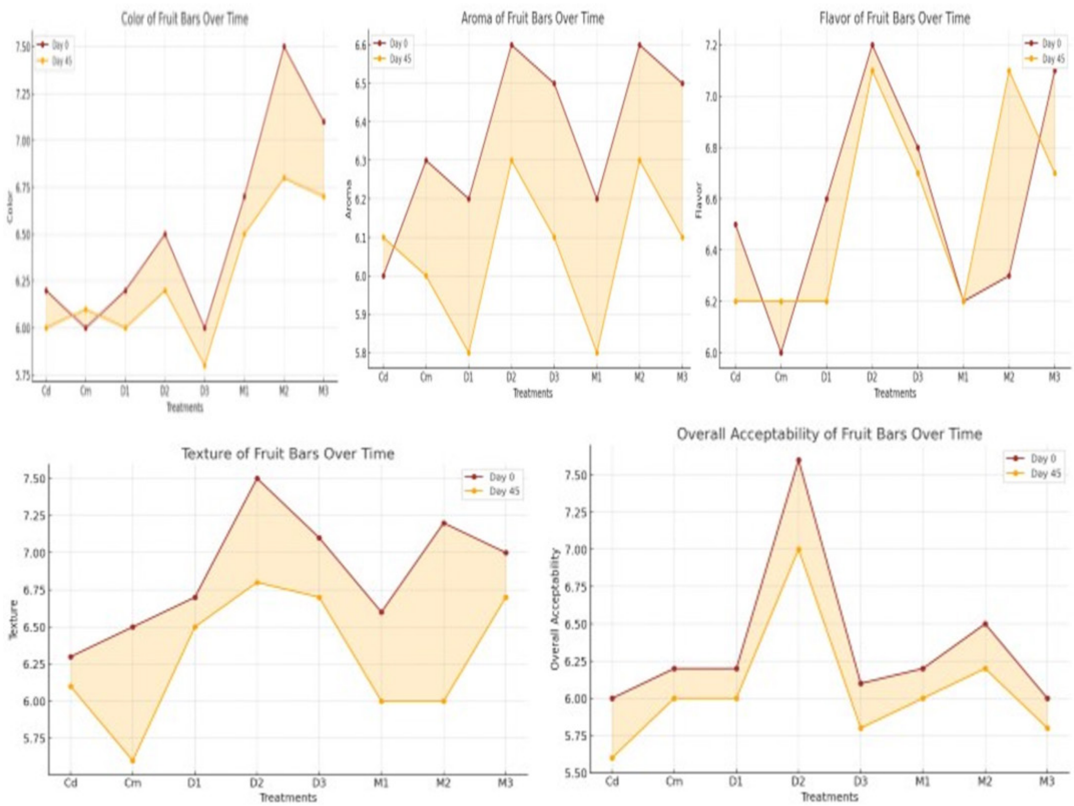

Figure 25. Sensory analysis of fruit bars.

Sensory analysis

The data presented in Figure 25 show that aroma, color, flavor, texture, and overall acceptability of fruit bars were significantly ($p < 0.01$) influenced by treatments, while interactions over days and the combined effect of treatments and days were non-significant ($p < 0.05$). Mean scores across treatments ranged from 6.5938 to 5.9688 for aroma, 7.1875 to 6.0938 for color, 7.1250 to 6.2674 for flavor, 6.9375 to 6.0035 for texture, and 7.1875 to 5.8750 for overall acceptability. The highest values observed on day 0 were 6.6250 (aroma, M2), 7.5000 (color, M2), 7.2500 (flavor, D2), 7.5000 (texture, D2), and 7.6250 (overall acceptability, D2). The lowest values, recorded on day 45, were 5.8750 (aroma, M1), 5.8750 (color, D3), 6.2500 (flavor, Cd), 5.6250 (texture, Cm), and 5.6250 (overall acceptability, Cd). These findings highlight clear variations in sensory attributes based on treatment formulations. Our results align with previous studies emphasizing the significant influence of treatments on sensory qualities such as aroma, color, flavor, texture, and overall acceptability—key factors for consumer satisfaction (Amalia *et al.*, 2022). These observations are consistent with research demonstrating that optimized treatments can enhance sensory characteristics, including texture and flavor, leading to improved consumer acceptability (Tagud *et al.*, 2024). Furthermore, our findings agree with studies showing that sensory stability can be maintained over storage time, ensuring long-term product quality (Verma & Bisen, 2020). The observed improvements in color and flavor support previous research highlighting the role of specific treatments in enhancing the visual appeal and taste of fruit bars (Devi *et al.*, 2018). Lastly, these results corroborate evidence suggesting that consumer preferences for sensory attributes can be optimized through ingredient modifications and controlled processing techniques (Akesowan *et al.*, 2020). Based on the findings, it can be concluded that fruit bars containing date and mango with 20% quinoa exhibited higher consumer acceptability compared to treatments with higher quinoa concentrations.

Conclusion

The development of mango and date-based fruit bars enriched with quinoa demonstrates significant potential as a nutritious and energy-rich snack suitable for all age groups. Quinoa, recognized as a nutrient-dense pseudo-cereal, serves as an excellent source of protein and energy, while mango and dates contribute essential nutrients, particularly minerals, making their combination in fruit bars highly beneficial. This study successfully prepared fruit bars under hygienic conditions, incorporating varying quinoa flour concentrations (10%, 20%, and 30%) with mango and date pulps. Comprehensive physical, chemical, microbiological, and sensory analyses conducted over a 45-day storage period revealed that the fruit bars maintained favorable nutritional and sensory profiles throughout storage. Notably, bars containing 30% quinoa showed a significant increase in protein, fiber, ash, and mineral contents. Significant variations in pH, acidity, sugar content, and brix values were observed across treatments and storage days. Additionally, quinoa-enriched bars exhibited significantly lower total plate and mold counts, indicating improved microbial stability. Among all formulations, the date bar with 20% quinoa flour demonstrated the highest acceptability across all sensory parameters, balancing nutritional benefits with consumer appeal. This study lays a promising foundation for the development of functional, nutrient-dense snacks that meet modern dietary demands while promoting health benefits. Furthermore, it highlights the versatility and health-promoting potential of quinoa-enriched fruit bars as convenient, nutrient-rich snacks. These findings also underscore the importance of further research into the health impacts of functional fruit bars and their potential role in disease prevention and management.

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Ethical Statement

The sensory evaluation was conducted following the guidelines established by the Ethics Committee of the Department of Human Nutrition, Faculty of Food Science and Nutrition, Bahauddin Zakariya University Multan, under approval number BZU/DHN/2023/04. Verbal informed consent was obtained from all individual participants, and this consent was documented via video recording. The study exclusively involved adult participants aged between 25 and 35 years, with no minors included.

Consent for Publication

All authors gave their verbal consent for publication of this article in this journal.

Data Availability

All relevant data are within the manuscript and its Supporting Information files.

Author Contributions

Conceptualization, Muhammad Bilal; methodology, Futrus Abid; software, Fozia Bakhtawar; validation, Nawal Al-Hoshani; formal analysis, Nida Firdous; investigation, Muhammad Mueed Tanveer; resources, Tariq Aziz; data curation, Syed Rafiq Hussain Shah.; writing—original draft preparation, Futurs Abid and Muhammad Bilal.; writing—review and editing, Fahad Al-Asmari; visualization, Fakhria A. Al-Joufi; supervision, Ashiq Hussain and Tariq Aziz.; project administration, Ashiq Hussain and Shafiq ur Rahman; funding acquisition, Tariq Aziz.

Conflict of Interest

The authors declare no conflict of interest.

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References

Agarwal, A., Rizwana, Tripathi, A.D., Kumar, T., Sharma, K.P., & Patel, S.K.S. (2023). Nutritional and functional new perspectives and potential health benefits of quinoa and chia seeds. Antioxidants, 12(7), 1413. https://doi.org/10.3390/antiox12071413

Aghajanzadeh, S., Ziaiifar, A.M., & Verkerk, R. (2023). Effect of thermal and non-thermal treatments on the color of citrus juice: A review. Food Reviews International, 39(6), 3555–3577. https://doi.org/10.1080/87559129.2021.2012799

Akesowan, A., Choonhahirun, A., & Jariyawaranugoon, U. (2020). Quality and sensory profile evaluation of gluten-free sapodilla-wild almond seed bar with stevia as partial sugar substitution. Food Research, 4(4), 1109–1115. https://doi.org/10.26656/fr.2017.4(4).421

Altuncevahir, İ.Ö., Erdoğan, E.Ö., & Yücesoy, S. (2024). Evaluation nutrients of Turkish snack bars based on labeling and web page information: A qualitative research. Journal of Food Quality and Hazards Control. https://doi.org/10.18502/jfqhc.11.2.15648

Amalia, M.R., Nuryani, N., & Santoso, B. (2022). Sensory Characteristics and Nutrient Content of Food Bar with Flour and Pumpkin Seed Substitution. Jurnal Ilmiah Kesehatan (JIKA), 4(1), 182–192. https://doi.org/10.36590/jika.v4i1.271

Amini, K., Sharifan, A., Ghiassi Tarzi, B., & Azizinezhad, R. (2022). Preparation of a low-calorie, gluten-free all-in-one cake mix, containing Bacillus Coagulans using quinoa and inulin functionality. Journal of Food Quality, 2022 (1), 8550086. https://doi.org/10.1155/2022/8550086

Angeli, V., Miguel Silva, P., Crispim Massuela, D., Khan, M.W., Hamar, A., Khajehei, F., & Piatti, C. (2020). Quinoa (Chenopodium quinoa Willd.): An overview of the potentials of the "golden grain" and socio-economic and environmental aspects of its cultivation and marketization. Foods, 9(2), 216. https://doi.org/10.3390/foods9020216

AOAC. (2000). Official methods of analysis (17th ed.). Association of Official Analytical Chemists.

Arinzechukwu, C.S., & Nkama, I. (2019). Production and quality evaluation of fruit bars from banana (Musa sapientum) and cashew (Anacardiumouest) apple fruit blends. Asian Food Science Journal, 10 (2), 1–16. https://doi.org/10.9734/AFSJ/2019/V10I230032

Aslam, H., Nadeem, M., Shahid, U., Ranjha, MMAN, Khalid, W., Qureshi, T.M., & Awuchi, C.G. (2023). Physicochemical characteristics, antioxidant potential, and shelf stability of developed roselle–fig fruit bar. Food Science & Nutrition, 11 (7), 4219–4232. https://doi.org/10.1002/fsn3.3436

Aziz, T., Qadir, R., Anwar, F., Naz, S., Nazir, N., Nabi, G., Haiying, C., Lin, L., Alharbi, M., Alasmari, A.F. (2024). Optimal Enzyme-Assisted Extraction of Phenolics from Leaves of Pongamia pinnata via Response Surface Methodology and Artificial Neural Networking. Appl Biochem Biotechnol. 196(9):6508–6525. https://doi.org/10.1007/s12010-024-04875-w

Barakat, H., & Alfheeaid, H.A. (2023). Date palm fruit (*Phoenix dactylifera*) and its promising potential in developing functional energy bars: Review of chemical, nutritional, functional, and sensory attributes. Nutrients, 15(9), 2134. https://doi.org/10.3390/nu15092134

Campos-Rodriguez, J., Acosta-Coral, K., & Paucar-Menacho, L.M. (2022). Quinua (Chenopodium quinoa): Composición nutricional y Componentes bioactivos del grano y la hoja, e impacto del tratamiento térmico y de la germinación. Scientia Agropecuaria, 13(3), 209–220. https://doi.org/10.17268/sci.agropecu.2022.019

Canela-Xandri, A., Balcells, M., Villorbina, G., Cubero, M.Á., & Canela-Garayoa, R. (2018).Effect of enzymatic treatments on dietary fruit fibre properties. Biocatalysis and Biotransformation, 2018, vol. 36.0, núm. 2, p. 172.0–179.0. https://doi.org/10.1080/10242422.2017.1313836

Carrizo, S.L., de LeBlanc, A.D.M., LeBlanc, J.G., & Rollán, G.C. (2020). Quinoa pasta fermented with lactic acid bacteria prevents nutritional deficiencies in mice. Food Research International, 127, 108735. https://doi.org/10.1016/j.foodres.2019.108735

Chau, C.F., & Cheung, P.K. (1997). Effect of various processing methods on antinutrients and in vitro digestibility of protein and starch of two Chinese indigenous vegetable seeds. Journal of Agricultural and Food Chemistry, 45 (12), 4773–4776. https://doi.org/10.1021/jf970504p

Christen, J.A., & Parker, A.E. (2020). Systematic statistical analysis of microbial data from dilution series. Journal of Agricultural, Biological and Environmental Statistics, 25 (3), 339–364. https://doi.org/10.1007/s13253-020-00397-0

Czech, A., Zarycka, E., Yanovych, D., Zasadna, Z., Grzegorczyk, I., & Kłys, S. (2020). Mineral content of the pulp and peel of various citrus fruit cultivars. Biological Trace Element Research, 193, 555–563. http://doi.org/10.1007/s12011-019-01727-1

Dakhili, S., Abdolalizadeh, L., Hosseini, S.M., Shojaee-Aliabadi, S., & Mirmoghtadaie, L. (2019). Quinoa protein: Composition, structure and functional properties. Food Chemistry, 299, 125161. https://doi.org/10.1016/j.foodchem.2019.125161

Dev, R., & Gupta, M. (2024). Elucidating the physical, chemical, functional and antioxidant properties of protein-rich quinoa (Chenopodium quinoa) crisp. Food and Humanity, 2, 100205. https://doi.org/10.1016/j.foohum.2023.100205

Devi, M., Vyas, S.R., & Kaur, J. (2018). Preparation and quality assessment of apple bar from different varieties. Asian Journal of Dairy and Food Research, 37(3), 242–245. https://doi.org/10.18805/AJDFR.DR-1354

Din, G.M.U., Rubab, Q., Hussain, A., Yaqub, S., Zulfiqar, N., Bibi, B., et al. (2024). Effect of lotus (Nelumbo Nucifera, G.) rhizome powder as a fat replacer on the quality attributes of muffins. Discover Food, 4(1), 158. https://link.springer.com/article/10.1007/s44187-024-00225-1

Eyiz, V., Tontul, İ., & Türker, S. (2020). The effect of edible coatings on physical and chemical characteristics of fruit bars. Journal of Food Measurement and Characterization, 14, 1775–1783. https://doi.org/10.1007/s11694-020-00425-0

Gahane, S., Relekar, P., Kadam, J., Shirke, G., Ranveer, R., & Rane, S. (2024). Development of sweet potato (Ipomoea batatas L.) and mango (Mangifera indica L.) blended bar. International Journal of Advanced Biochemistry Research, 8(3): 551–557. https://doi.org/10.33545/26174693.2024.v8.i3g.773

Garre, A., Egea, JA, Esnoz, A., Palop, A., & Fernandez, PS (2019). Tail or artifact? Illustration of the impact that uncertainty of the serial dilution and cell enumeration methods has on microbial inactivation. Food Research International, 119, 76–83. https://doi.org/10.1016/j.foodres.2019.01.059

Gireesh, A., Mishra, S., Vishen, G.S., Gopan GM, V., & Jose, P. (2022). Studies on Preparation and Value Addition on Guava Fruit Bar. International Journal of Plant & Soil Science, 34(22), 610–616. https://doi.org/10.9734/ijpss/2022/v34i2231414

Gómez, M.J.R., Prieto, J.M., Sobrado, V.C., & Magro, P.C. (2021). Nutritional characterization of six quinoa (Chenopodium quinoa Willd) varieties cultivated in Southern Europe. Journal of Food Composition and Analysis, 99, 103876. https://doi.org/10.1016/j.jfca.2021.103876

Gorsi, F.I., Hussain, A., Kausar, T., Nisar, R., Siddique, T., Yaqub, S., et al. (2024). Structural and thermal interaction studies of aloe vera (aloe barbadensis miller) gel powder and developed food bars. Journal of Thermal Analysis and Calorimetry, 149(10), 4543–4559. https://link.springer.com/article/10.1007/s10973-024-13007-9

Hernández-Ledesma, B. (2019). Quinoa (Chenopodium quinoa Willd.) as source of bioactive compounds: A review. Bioactive Compounds in Health and Disease-Online ISSN: 2574-0334;

Print ISSN: 2769-2426, 2(3), 27–47. https://doi.org/10.31989/bchd.v2i3.556

Hernández-Maldonado, L.M., Blancas-Benítez, F.J., Zamora-Gasga, V.M., Cárdenas-Castro, A.P., Tovar, J., & Sáyago-Ayerdi, S.G. (2019). In vitro gastrointestinal digestion and colonic fermentation of high dietary fiber and antioxidant-rich mango (*Mangifera indica* L.) "Ataulfo"-based fruit bars. Nutrients, 11 (7), 1564. https://doi.org/10.3390/nu11071564

Hossain, A.B.M. Sharif. (2019). Glucose, TSS and nutrient content of dates, mango, apple and banana: A comparative study. International Journal of Bioscience and Biochemistry. 1. 18–20. https://doi.org/10.33545/26646536.2019.v1.i1a.6

Hussain, A., Kausar, T., & Din, A. (2023). Development, standardization, physico-chemical and nutritional analysis of biscuits developed with different replacement levels of pumpkin flesh powder. J. Agric. Res, 61(1), 220

Hussain, A., Kausar, T., Siddique, T., Kabir, K., An, Q.U., Rukhsar, F., et al. (2024a). Physiological and biochemical variations of naturally ripened mango (*Mangifera Indica* L.) with synthetic calcium carbide and ethylene. Scientific Reports, 14(1), 2121. https://www.nature.com/articles/s41598-024-52483-9

Hussain, A., Rehman, A., Kauser, S., Ali, A., Arif, M.R., Fatima, H., et al. (2024b). Evaluation of peel, flesh, and kernel of mango (*Mangifera indica* L.) for phytochemicals and application as functional ingredients in bakery formulation. Nutrire, 49(2), 45. https://link.springer.com/article/10.1186/s41110-024-00288-1

Hussain, M.I., Farooq, M., Syed, Q.A., Ishaq, A., Al-Ghamdi, A.A., & Hatamleh, A.A. (2021). Botany, nutritional value, phytochemical composition and biological activities of quinoa. Plants, 10(11), 2258. https://doi.org/10.3390/plants10112258

Jufri, N., Marliyati, S.A., Anwar, F., & Ekayanti, I. (2023). Date milk enriched with vitamin D: nutrient content and acceptability as a food additive for preschoolers 48–59 months. Bio Rxiv, 2023–05. https://doi.org/10.1101/2023.05.15.540750

Kamau, J., Mwaura, F., Mwaniki, J., & Mbui, D. (2020). Proximate analysis of fruits and vegetables wastes from Nairobi County, Kenya. Research Journal of Food Science and Nutrition, 5(1), 9–15. http://doi.org/10.31248/RJFSN2019.088

Kaur, R., Ahluwalia, P., Sachdev, P.A., & Kaur, A. (2018). Development of gluten-free cereal bar for gluten intolerant population by using quinoa as major ingredient. Journal of Food Science and Technology, 55, 3584–3591. https://link.springer.com/article/10.1007/s13197-018-3284-x

Kigozi, J., Wandeka, C.M., Mugabi, R., & Ainebyona, P. (2024). Optimization of hardness as a textural property of a fruit enriched honey sweetened snack bar for children aged 5 to 13 Years. European Journal of Agriculture and Food Sciences, 6(4), 14–18. https://doi.org/10.24018/ejfood.2024.6.4.733

Li, G., & Zhu, F. (2018). Quinoa starch: Structure, properties, and applications. Carbohydrate Polymers, 181, 851–861. https://doi.org/10.1016/j.carbpol.2017.11.067

Li, T., Liang, M., Li, Z., Gu, F., Guo, Q, Wang, Q. (2025). Synthesis of novel resveratrol nervonic acid ester using a solvent-free mechanochemical method: Improved lipophilicity, thermostability, and oxidation stability. Food Chemistry, 480, 143958. doi: https://doi.org/10.1016/j.foodchem.2025.143958

Mahnoor, Ainee, A., Hussain, A., Kausar, T., Bibi, B., Kabir, K., et al. (2024). Effect of water chestnut based edible coating on the physicochemical quality and shelf life of apples. Discover Applied Sciences, 6(8), 442. https://link.springer.com/article/10.1007/s42452-024-06114-7

Maldonado-Celis, M.E., Yahia, E.M., Bedoya, R., Landázuri, P., Loango, N., Aguillón, J., & Guerrero Ospina, J.C. (2019). Chemical composition of mango (Mangifera indica L.) fruit: Nutritional and phytochemical compounds. Frontiers in Plant Science, 10, 1073. https://doi.org/10.3389/fpls.2019.01073

Manasa, B., Jagadeesh, S.L., & Thammaiah, N. (2019). Colour measurement of ripening mango fruits as influenced by pre-harvest treatments using L* a* b* coordinates. Journal of Pharmacognosy and Phytochemistry, 8(1), 2466–2470.

Melini, V., & Melini, F. (2021). Functional components and anti-nutritional factors in gluten-free grains: A focus on quinoa seeds. Foods, 10(2), 351. https://doi.org/10.3390/foods10020351

Munir, M., Nadeem, M., Qureshi, T.M., Qayyum, A., Suhaib, M., Zeb, F., & Ashokkumar, M. (2018). Addition of oat enhanced the physico-chemical, nutritional and sensory qualities of date fruit based snack bars. Journal of Food and Nutrition Research, 6 (4), 271–276. https://doi.org/10.12691/jfnr-6-4-10

Olabinjo, O.O., Sama, M.O., & Babatope, O.S. (2022). Evaluation of nutritional composition of ripe date fruit (Phoenix Dactylifera L.) pulp and seed grown in Nigeria. International Journal of Environment Agriculture and Biotechnology, 7, 123–28. https://doi.org/10.22161/ijeab.75.12

Ozilgen, S. (2011). Influence of chemical composition and environmental conditions on the textural properties of dried fruit bars. Czech Journal of Food Sciences, 29(5), 539–547. https://doi.org/10.17221/303/2009-CJFS

Padmashree, A., Negi, N., Haridas, S., Govindaraj, T., Kumar, K.R.A., Semwal, A.D., & Sharma, G.K. (2018). Development and quality evaluation of choco quinoa nutri bar during storage. Food and Nutrition Sciences, 9(7), 899–914. https://doi.org/10.4236/fns.2018.97067

Pathan, S., & Siddiqui, R.A. (2022). Nutritional composition and bioactive components in quinoa (Chenopodium quinoa Willd.) greens: A review. Nutrients, 14(3), 558. https://doi.org/10.3390/nu14030558

Pellegrini, M., Lucas-Gonzales, R., Ricci, A., Fontecha, J., Fernández-López, J., Pérez-Álvarez, J.A., & Viuda-Martos, M. (2018). Chemical, fatty acid, polyphenolic profile, techno-functional and antioxidant properties of flours obtained from quinoa (Chenopodium quinoa Willd) seeds. Industrial Crops and Products, 111, 38–46. https://doi.org/10.1016/j.indcrop.2017.10.006

Pertiwi, N.N., Putra, E.D.L., & Harun, F.R. (2022). Determination of macro mineral content in fresh Noni Fruit (Morinda Citrifolia L.) by atomic absorption spectrophotometry. International Journal of Science, Technology & Management, 3(5), 1392–1395. http://doi.org/10.46729/ijstm.v3i5.612

Rasouli, M., Saba, M.K., & Ramezanian, A. (2019). Inhibitory effect of salicylic acid and Aloe vera gel edible coating on microbial load and chilling injury of orange fruit. Scientia Horticulturae, 247, 27–34. https://doi.org/10.1016/J.SCIENTA.2018.12.004

Romano, N., Ureta, M.M., Guerrero-Sánchez, M., & Gómez-Zavaglia, A. (2020). Nutritional and technological properties of a quinoa (Chenopodium quinoa Willd.) spray-dried powdered extract. Food Research International, 129, 108884. https://doi.org/10.1016/j.foodres.2019.108884

Sabeel V, A., Wani, K.M., Dubey, P.K., Reddy, M.V.K., & Kumar, S. (2024). Pseudocereals and dates as potential ingredients in nutrition bars: a review. Nutrire, 49(2), 38. https://link.springer.com/article/10.1186/s41110-024-00281-8

Sahu, A., Kishore, K., Nayak, R.K., Dash, S.N., Sahoo, S.C., & Barik, S. (2023). Influence of potassium on mineral content, yield and quality attributes of dragon fruit (*Selenicereus monacanthus*) in acidic soil of Eastern tropical region of India. Journal of Plant Nutrition, 46(11), 2621–2636. http://doi.org/10.1080/01904167.2022.2160744

Saletnik, B., Bajcar, M., Saletnik, A., Zaguła, G., & Puchalski, C. (2021). Effect of the pyrolysis process applied to waste branches biomass from fruit trees on the calorific value of the biochar and dust explosivity. Energies, 14(16), 4898. https://doi.org/10.3390/en14164898

Salomón-Torres, R., Ortiz-Uribe, N., Valdez-Salas, B., Rosas-González, N., García-González, C., Chávez, D., & Krueger, R. (2019). Nutritional assessment, phytochemical composition and antioxidant analysis of the pulp and seed of medjool date grown in Mexico. PeerJ, 7, e6821. https://doi.org/10.7717/peerj.6821

Shaikh, R.N., Agarkar, B.S., Kshirsagar, R.B., & Bachate, A.H. (2021). Studies on physical, chemical and mineral evaluation of mango (*Mangifera indica* L.). The Pharma Innovation Journal, 10(6), 446–449.

Shouket, S., khurshid, S., Khan, J., Nadeem, A.A., Sarwar, A., Aziz, T., Alotaibi, N.M., Alamari, A.S., Alhomrani, M., Sameeh, M.Y. (2024) Biosynthetically produced glucose oxidase immobilized silver nanoparticle bioconjugate treatment improves the shelf life of mango fruit: an innovative method towards food safety and sustainability. Biomass Conv. Bioref. 14, 31357–31368. https://doi.org/10.1007/s13399-023-04753-1

Siddique, F., Hussain, A., Mahdi, A.A., Hassan, M., Noreen, S., Siddique, T., et al. (2024). Comparison of Chemically Treated, Pasteurized, and Microwave-Treated (at Different Time Durations) Chia Seeds Added To Mango-Whey Beverage, during Different Storage Periods, for Physicochemical and Sensory Parameters. Journal of Food Quality, 2024(1), 6688945. https://doi.org/10.1155/2024/6688945

Srivastava, A., Kohli, D., Vishnoi, S., Kumar, S., & Badola, R. (2019). Quality evaluation of prepared guava-orange fruit bar. International Journal of Chemical Studies, 7(4), 1574–1581.

Tagud, J.M.J., Baclayon, M.B., & Agoylo Jr, J.C. (2024). Evaluation of the Organoleptic Properties of Calabash Fruit (Crescentia Cujete) Jam: A Comprehensive Sensory analysis. International Journal of Latest Technology in Engineering, Management & Applied Science, 13(8), 13–23. https://doi.org/10.51583/ijltemas.2024.130802

Tsegay, Z.T. (2020). Total titratable acidity and organic acids of wines produced from cactus pear (Opuntia-ficus-indica) fruit and Lantana camara (L. Camara) fruit blended fermentation process employed response surface optimization. Food science & nutrition, 8(8), 4449–4462. https://doi.org/10.1002/fsn3.1745

Ud Din, G.M., Usmani, W., Hussain, A., Bilal, M., Najam, A., Zia, M., Siddique Raza, M., Aziz, T., Zahra, N., Alshammari, J. M., Alharbi, M.H., & Al-Asmari, F. (2025). Effect of multigrain flour mixes on the physicochemical, nutritional, textural, and sensory quality of cake rusks. Italian Journal of Food Science, 37(2), 261–275. https://doi.org/10.15586/ijfs.v37i2.2921

Umar, Y., Hashim, H., & Muhammad, Z.U. (2021). Proximate and quantitative phytochemical analysis of Detarium microcarpum fruit pulp. Journal of Biology, Agriculture and Healthcare, 11(16), 16–22. http://doi.org/10.7176/jbah/11-16-04

Väkeväinen, K., Ludena-Urquizo, F., Korkala, E., Lapveteläinen, A., Peräniemi, S., von Wright, A., & Plumed-Ferrer, C. (2020). Potential of quinoa in the development of fermented spoonable vegan products. Lwt, 120, 108912. https://doi.org/10.1016/j.lwt.2019.108912

Verma, R., & Bisen, B.P. (2020). Studies on sensory evaluation of guava and papaya mixed fruit bar during storage. Journal of Pharmacognosy and Phytochemistry, 9(4), 1052–1056.

Villacrés, E., Quelal, M., Galarza, S., Iza, D., & Silva, E. (2022). Nutritional value and bioactive compounds of leaves and grains from quinoa (Chenopodium quinoa Willd.). Plants, 11(2), 213. https://doi.org/10.3390/plants11020213

Wang, S., Fang, Y., Xu, Y., Zhu, B., Piao, J., Zhu, L, Wu, J. (2022). The effects of different extraction methods on physicochemical, functional and physiological properties of soluble and insoluble dietary fiber from Rubus chingiiHu. fruits. Journal of Functional Foods, 93, 105081. doi: https://doi.org/10.1016/j.jff.2022.105081

Yan, Y., Feng, L., Shi, M., Cui, C., & Liu, Y. (2020). Effect of plasma-activated water on the structure and in vitro digestibility of waxy and normal maize starches during heat-moisture treatment. Food chemistry, 306, 125589. https://doi.org/10.1016/j.foodchem.2019.125589

Yulistiani, R., & Sarofa, U. (2022). Utilization of fruit extract as acidulant on physicochemical and sensory properties of cottage cheese with addition calcium chloride. AJARCDE (Asian Journal of Applied Research for Community Development and Empowerment), 6(2), 15–21. https://doi.org/10.29165/ajarcde.v6i2.95

Zhang, Q., Li, H., Zheng, R., Cao, L., Zhang, S., Zhang, S., Fu, L. (2024). Comprehensive analysis of advanced glycation end-products in commonly consumed foods: presenting a database for dietary AGEs and associated exposure assessment. Food Science and Human Wellness, 13(4), 1917–1928. doi: https://doi.org/10.26599/FSHW.2022.9250159

Zhang, Y., Zhang, Y., Li, B., Wang, X., Xu, F., Zhu, K., et al. (2019). In vitro hydrolysis and estimated glycemic index of jackfruit seed starch prepared by improved extrusion cooking technology. International Journal of Biological Macromolecules, 121, 1109–1117. https://doi.org/10.1016/j.ijbiomac.2018.10.075

Zhou, S., Hong, Y., Gu, Z., Cheng, L., Li, Z., & Li, C. (2020). Effect of heat-moisture treatment on the in vitro digestibility and physicochemical properties of starch-hydrocolloid complexes. Food Hydrocolloids, 104, 105736. https://doi.org/10.1016/j.foodhyd.2020.105736