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Research Paper / Araştırma Makalesi

Effect of Dietary Fiber Enrichment on Quality Characteristics and Consumer Acceptance of Fruit Snacks

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ABSTRACT

In this study, different fiber sources such as inulin, peas and carrots were used to produce fruit snacks enriched with dietary fiber. The effect of these fiber sources on the proximate composition, pH, titratable acidity, water activity, color, texture, total phenolic content, microbial load, and sensory acceptability of fruit snacks was determined. Results showed that fruit snacks enriched with inulin (5.0%) had the highest content of total dietary fiber while snacks enriched with carrot fiber (5.0%) had the highest total phenolic content. The moisture content of fruit snacks with different fibers decreased in comparison to control snacks as fiber was added into their formulation. Moreover, the water activity values of fruit snacks (a_w) were lower than 0.7, indicating a low risk for bacterial growth and affirming a favorable shelf life. Compared to control snacks, increasing the dietary fiber addition from 2.5 to 5.0% significantly increased the hardness, gumminess and chewiness values of fruit snacks. The microbiological analysis of fruit snacks indicated that snacks were safe. Additionally, results showed that fruit snacks (2.5%) enriched with inulin and pea fiber were found to have higher sensory acceptability scores than others.

Keywords: Fruit pastes, Snack, Inulin, Pea fiber, Carrot fiber, Quality properties

Meyveli Atıştırmalıkların Diyet Lifiyle Zenginleştirilmesinin Kalite Özellikleri ve Tüketici Kabulüne Etkisi

ÖZ

Bu çalışmada, diyet lifi ile zenginleştirilmiş meyveli atıştırmalıklarının üretilmesi amacıyla inülin, bezelye ve havuç lifi gibi farklı lif kaynakları kullanılmıştır. Farklı lif kaynaklarının meyve atıştırmalıklarının temel bileşimi, pH, titre edilebilir asitlik, su aktivitesi, renk, tekstür, toplam fenolik madde içeriği, mikrobiyal yük ve duyusal kabul edilebilirliği üzerindeki etkileri incelenmiştir. Sonuç olarak, inülin ile zenginleştirilmiş meyve atıştırmalığının (%5.0) en yüksek toplam diyet lifi içeriğine sahip olduğu belirlenirken, diğer yandan havuç lifi (%5.0) ile zenginleştirilmiş meyve atıştırmalığı ise en yüksek toplam fenolik madde içeriğindedir. Formülasyona diyet lifi ilave edildiğinde, kontrol grubuna göre meyve atıştırmalığı örneklerinin nem içeriği azalmıştır. Ayrıca, örneklerin su aktivitesi değerlerinin 0.70'in altında olduğu belirlenmiş olup, bu da bakteriyel gelişme riskinin düşük olduğunu ve raf ömrünün de uzun olduğunu göstermektedir. Kontrol grubuna kıyasla, meyve atıştırmalıklarına ilave edilen lif içeriğinin %2.5'ten %5.0'a çıkarılması durumunda, örneklerin sertlik, sakızımsılık ve çiğnenebilirlik değerlerini önemli ölçüde artmıştır. Meyve atıştırmalıklarının mikrobiyal analiz sonuçlarına göre, örneklerin mikrobiyolojik olarak güvenli olduğunu belirlenmiştir. Ayrıca, bu çalışmada elde edilen sonuçlara dayanarak, inülin ve bezelye lifi ile zenginleştirilmiş meyve atıştırmalıklarının (%2.5) diğerlerine göre daha yüksek duyusal kabul edilebilirliğe sahip olduğu görülmüştür.

Anahtar Kelimeler: Meyve ezmesi, Atıştırmalık, İnülin, Bezelye lifi, Havuç lifi, Kalite özellikleri

INTRODUCTION

Many consumers frequently enjoy snack products available on the market, often including chocolates, chips, and wafers that are high in fat, refined sugar, and calories. Manufacturers of these snacks frequently emphasize taste over nutritional content. However, in recent times, there has been a notable increase in the demand for healthier snack alternatives that are rich in vitamins, minerals, and dietary fiber while containing minimal amounts of oil. This shift in consumer preferences is driven by a heightened awareness of the health impact of their dietary choices [1].

Fruits are essential for sustaining a balanced and nourishing diet because they provide a wealth of energy, dietary fiber, minerals, and vitamins. Fruit snacks are concentrated fruit-based products including the mixture of various fruit pastes and nuts, which have high nutritional value with long shelf life and can be classified as confectionery [2]. A fruit snack such as fruit bar, ball, freeze-dried fruits, impregnated fruits serve as a convenient option for enjoying fruits even when they are out of season, and it offers concentrated nutritional value as it is made from dried fruits. The production of fruit snacks can vary significantly among different manufacturers, depending on their unique formulation and processes. Ingredients like fruit pulp, both fresh and dried fruits, sugars (such as sucrose, maltodextrin, glucose syrup, and fruit juice concentrates), binding agents (like pectin, glycerol, and various carbohydrates especially fibers), and additional components like colorants, flavors, and acids can all be utilized in the manufacturing of these tasty snacks [3]. Consumption of fruit-based snacks has increased the intake of nutrients and phytochemicals, resulting in beneficial health effects and potentially aiding individuals in achieving the recommended daily intake.

Food fortification or enrichment is the process of adding essential nutrients to a food product, regardless of whether these nutrients are naturally found in the food, in order to prevent or address deficiencies within the population. Fruit-based bars are economical and convenient functional foods that can replace fresh fruits and vegetables as a source of various essential nutrients. As consumer demand for healthy, natural, and convenient food choices continues to increase, fruit-based snacks are becoming increasingly popular and can serve as excellent options for delivering health benefits to consumers [4].

Dietary fibers (DF) comprise the edible portions of fruits and vegetables that resist digestion by human enzymes and absorption in the small intestine, resulting in a fermentation process carried out by gut microbiota in the large intestine. DF exhibits diverse physiological properties, influenced by its solubility, physicochemical characteristics, and two fractions: insoluble fiber (IF) and soluble fiber (SF). On one hand, IF primarily enhances fecal bulk due to its porosity and low density, stimulates intestinal motility, increases defecation frequency, thus reducing transit time, and traps toxins. On the other hand, SF is more prone to fermentation by colonic bacteria, influencing gut microbiota and generating short-chain fatty acids, regulates satiety, forms gels that lower blood glucose and moderate plasma cholesterol levels, and enhances viscosity, reducing glycemic response and limiting the absorption of cholesterol and free fatty acids [5, 6].

The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) advise a daily intake of over 25 grams of DF, primarily sourced from consuming 400 grams of fruits and vegetables. Furthermore, insufficient DF intake is linked to diseases such as obesity, diabetes mellitus, inflammatory bowel disorders, various types of cancer, constipation, and diverticulosis. To combat these health issues, the food industry is actively developing DF-enriched foods to encourage greater DF consumption. In pursuit of this goal, the food industry is exploring new DF sources [6, 7].

While processing fruits and vegetables like apples, oranges, carrots, peas, etc. various by-products are generated, containing valuable compounds. Notably, the fiber component stands out for its significant potential in creating functional foods. Plant fibers exhibit specific functional attributes, including their ability to retain water and expand in volume. Key features of commercially available plant fibers include a dietary fiber content exceeding 50%, moisture content below 9%, minimal lipid content, low calorie level, and a neutral flavor profile [8].

Due to the health benefits of dietary fiber enrichment for fruit-based snacks, there is a tendency to make a nutrition claim in the development of fruit snacks. According to the Food and Drug Administration (FDA), to have a food product with a ‘‘high in fiber’’ or “excellent source of fiber” and ‘‘good source of fiber’’ claim, it must contain, 20% or more fiber and 10-19% of fiber of the recommended daily value for dietary fiber in a serving size, respectively [5]. In the Turkish Food Codex, the food must contain at least 6 g of fiber in 100 g of product to make ‘‘high in fiber’’ or “excellent source of fiber” claim [9].

Fiber-enriched fruit snacks offer a combination of health benefits, convenience, and taste, making them an important component of a balanced and nutritious diet. In addition, high-fiber snacks can contribute to a feeling of fullness, reducing overall calorie intake and supporting weight management efforts. The fiber-enriched fruit snacks provide a convenient and portable way to incorporate healthy foods into a busy lifestyle. They are easy to pack and consume, making them suitable for various settings, including work, school, or travel. The popularity of fiber-enriched fruit snacks can drive innovation in the food industry, leading to the development of new, healthier snack options. Therefore, the food industry is currently exploring alternative plant fiber sources to increase total fiber content of fruit snacks while maintaining the quality characteristics and consumer acceptability of enriched fruit snacks.

Currently, there is a lack of research regarding the enrichment of various dietary fibers in fruit snacks produced by date and apricot paste which are highly nutritious containing minerals, vitamins, and digestible carbohydrates. Thus, the objective of this study was to assess the fiber enrichment at levels of 2.5% and 5% of plant fibers impacts the chemical, physical, microbial, and sensory characteristics of these snacks. In addition, making fiber claim on the label of enriched fruit snacks will also be evaluated.

MATERIALS and METHODS

Materials

Pasteurized fruit pastes (apricot and date) were supplied from a local company in İzmir, Türkiye. Different fibers as inulin (Vegrano, Belgium), pea fiber (Miller, Turkey), and carrot fiber (Unipektin, Germany) were used for enrichment studies. Sunflower oil (Yudum, Türkiye) was used in the formulation of fruit snacks. All chemicals used for analysis was purchased from Sigma Aldrich with analytical grade (Darmstadt, Germany). Peptone and mediums for microbiological analysis also purchased from Merck (Darmstadt, Germany).

Methods

Production of Fruit Snacks

Fruit snacks were prepared according to the formulations given in Table 1. After weighing the ingredients, all materials without sunflower oil were blended using a mixer for 5 min until a homogeneous mixture was obtained. Then, the pieces were taken as 10 ± 0.5 g and manually shaped as ball. The sunflower oil was used in shaping step to prevent sticking the snacks. After that, fruit snacks were rested at room temperature (20 ± 2 °C) for 24 h before packaging. 100 g of fruit snacks were packed in polyethylene bags and stored at room temperature for further analysis.

Table 1. Formulations of fruit snacks enriched by various plant fibers

Code	Sample name	Type of dietary fiber added	Formulation
C	Control	-	50% apricot paste, 49.5% date paste, 0.5% sunflower oil
I-1	Inulin enriched fruit snack-1	Inulin	50% apricot paste, 47% date paste, 2.5% inulin, 0.5% sunflower oil
I-2	Inulin enriched fruit snack-2	Inulin	50% apricot paste, 44.5% date paste, 5% inulin, 0.5% sunflower oil
PF-1	Pea fiber enriched fruit snack-1	Pea fiber	50% apricot paste, 47% date paste, 2.5% pea fiber, 0.5% sunflower oil
PF-2	Pea fiber enriched fruit snack-2	Pea fiber	50% apricot paste, 44.5% date paste, 5% pea fiber, 0.5% sunflower oil
CF-1	Carrot fiber enriched fruit snack-1	Carrot fiber	50% apricot paste, 47% date paste, 2.5% carrot fiber, 0.5% sunflower oil
CF-2	Carrot fiber enriched fruit snack-2	Carrot fiber	50% apricot paste, 44.5% date paste, 5% carrot fiber, 0.5% sunflower oil

General Composition Analysis and Energy Content

The proximate composition including moisture, ash, protein, fat, and total dietary fiber of fruit snacks was determined by AOAC [10]. The total carbohydrates (%) were calculated by differences from the protein, fat, moisture, ash, and crude fiber contents (Eq. 1). Total energy content of fruit snacks was calculated by Equation 2. All measurements were performed in triplicate.

$$\text{Total Carbohydrate (\%)} = [100 - (\text{Protein} + \text{Fat} + \text{Moisture} + \text{Ash} + \text{Fiber})] \quad \text{(Eq.1)}$$

$$\text{Energy (kcal/100 g)} = \text{Protein} * 4 + \text{Carbohydrate} * 4 + \text{Fat} * 9 \quad \text{(Eq.2)}$$

pH, Total Titratable Acidity and Water Activity

The pH of the fruit snacks was measured in a suspension obtained from a mixture of 5 g of sample with 50 mL of deionized water, using a pH meter (Radiometer Analytical, PHM210, France). Total titratable acidity was determined by potentiometric titration method with 0.1 N NaOH and the results were reported as g of citric acid/100 g of sample. Water activity of fruit snacks was determined using a water activity meter (Rotronic, HygroPalm AW, Switzerland) at 25 °C.

Color

The L*, a* and b* values of fruit snacks were determined using a Chroma meter CM-5 (Konica Minolta, Tokyo, Japan), which had been calibrated using a standardized white plate. Color difference (ΔE*) and chroma (C*) of fruit snacks compared to control snack, which has no fiber addition, was calculated using Equation 3 and 4, respectively.

$$Color\ difference\ (\Delta E^*) = \sqrt{\left(L^* - L^*_{ref}\right)^2 + \left(a^* - a^*_{ref}\right)^2 + \left(b^* - b^*_{ref}\right)^2} \quad \text{(Eq. 3)}$$

$$Chroma\ (C^*) = \sqrt{a^{*2} + b^{*2}} \quad \text{(Eq. 4)}$$

Texture

Textural properties such as hardness, adhesiveness, cohesiveness, gumminess, and chewiness are important features of fruit snacks. To assess the texture profile analysis of the fruit snacks, a texture analyzer (TA-XT2 Plus, Stable Microsystems, UK) equipped with a 36 mm cylindrical probe and 5 kg of load cell was employed. The analysis involved the use of 8 different fruit snacks. The sample underwent compression to a depth of 30% at a pre-test speed of 1 mm/s, followed by testing at a speed of 3 mm/s, and finally, post-testing at a speed of 10 mm/s [3].

Total Phenolic Content

The total phenolic content of fruit snacks was determined as described by Singleton & Rossi [11], using the Folin-Ciocalteu method. In order to prepare the fruit extract before analysis, 5 grams of the fruit snack homogenized in 50 mL of ethanol (80%) at 10,000 rpm for 2 minutes. Afterward, the mixture was gently stirred at 200 rpm in a water bath maintained at a temperature of 40°C for 2 hours. Finally, the extract was obtained by filtering the mixture through a filter paper [1]. a 0.50 mL aliquot of the diluted sample was combined with 2.5 mL of a Folin–Ciocalteu reagent diluted at a 1:10 ratio. Following a 5-minute incubation at room temperature, 2 mL of a saturated Na_2CO_3 solution (75 g/L) was added to the mixture. After allowing the mixture to incubate for 2 hours at room temperature in dark, its absorbance was measured at 760 nm by a UV-VIS spectrophotometer (Thermo Scientific, Genesys-10S). Gallic acid used as the reference standard, and the results were expressed as milligrams of gallic acid equivalents per 100 g of fruit snack (mg GAE/100 g).

Total Aerobic Mesophilic Bacteria and Yeast and Mold Count

Total aerobic mesophilic bacteria (TAMB) and yeast & mold counts (YM) of fruit snacks were determined according to FDA's Bacteriological Analytical Manual [12]. For microbiological analysis, 25 g of fruit snack was put inside a stomacher bag and 225 mL of buffered peptone water (0.1%) was added. Then, the mixture was homogenized in a stomacher (Interscience, Bag Mixer 400). Serial dilutions were made in sterile peptone water and used for enumeration of microorganisms. TAMB and YM counts were determined by pour plate method onto PCA (Plate Count Agar) and spread plate method onto DRBC (Dichloran Rose Bengal Chloramphenicol Agar), respectively. Petri plates were incubated at 35°C for 48 h and 25°C for 5 days, respectively for TAMB and YM counts. The mean values were obtained by conducting the tests in triplicate and the results were given as log CFU/g.

Sensory Analysis

Sensory analysis was conducted by 20 untrained panelists, according to Otunola et al. [13]. Panelists were willing consumers of fiber-enriched fruit snacks. Samples were portioned, coded using 3-digit numbers and served on plastic plates at ambient temperature. Panelists evaluated odor, color, flavor, texture, appearance, overall acceptance, and FACT (willingness to eat the product if it was available on the market) values using a 7-point scale, going from "1 - only if forced, I would eat this fruit ball" to 7 - "I would eat this fruit ball every time I had the chance".

Statistical Analysis

The statistical differences between the fruit snacks were evaluated by one-way analysis of variance (ANOVA) (SPSS 20, New York). The multiple comparison test as Duncan's Multiple Range test were used to measure specific differences between pairs of means ($P < 0.05$), and results were expressed as mean ± standard deviation.

RESULTS and DISCUSSION

pH, water activity, acidity, and total phenolic content of control and fiber-enriched fruit snacks were given in Table 2. pH of control group and fiber enriched fruit snacks were determined in the range of 4.86-5.04. Compared to the control group, pH values of fiber-enriched snacks were significantly different ($p<0.05$) except for fruit snack enriched with 2.5% of pea fiber (PF-1). The pH values of samples I-2 and PF-2 were found to be similar, and likewise, there was no statistically significant difference in the pH values between samples I-2 and CF-2 ($p>0.05$). The increase in pH observed particularly in groups where 5% dietary fiber was added compared to the control group could be due to the neutral pH characteristics of plant fibers and the quantitative decrease in date paste in the formulation, resulting in an increase in the pH value of the fruit snack. In a study, the pH of fruit bar formulated by date and apple pulp was 4.30-5.28 [14]. It was observed that consistent results in line with the literature had been obtained.

Water activity measurements play a crucial role in predicting the textural attributes, stability, and shelf life of food products. As seen in Table 2, it is observed that the water activity values of fruit snacks enriched with dietary fiber show a decrease, ranging between 0.61 to 0.69. The highest water activity value was observed in the control group (C), while the lowest water activity was observed in CF-2. Compared to the control group, the changes in water activities of fiber-enriched samples were found to be statistically significant. The water

activity values of I-1, I-2, and PF-1 samples were found to be similar ($p>0.05$). a_w values were well below 0.7, indicating a low risk of microbial proliferation, potential pathogenic spoilage, and affirming a favorable shelf life [15]. Similarly, a study reported that the water activity of snack bar produced by date paste was 0.613±0.005 [16]. In another study, the moisture content and water activity levels of the formulated date bars, ranging from 33.59% to 34.67% and 0.60 to 0.65, respectively, were consistent with the established moisture (20-40%) and water activity (0.70-0.90) criteria for intermediate moisture (IM) foods [17]. In this study, the reason for the decrease in water activity values in fruit snacks enriched with dietary fiber is thought to be the decrease of date paste from the formulation and the addition of powdered fiber with very low moisture content.

Acidity is a critical factor in determining the quality of fruit, impacting not just how we perceive its tartness but also its sweetness. Titratable acidity stands out as the primary indicator of acidity, closely tied to our perception of sourness. Furthermore, pH levels also play a role in shaping our perception of acidity. Sensory analysis experiments using synthetic acid solutions have confirmed that the perception of acidity is strongly linked to titratable acidity, with pH having a somewhat less pronounced effect on this perception [18]. Furthermore, the sensory appeal of fruit is greatly influenced by its acidity, primarily owing to the abundance of malic and citric acids, which are the dominant organic acids in most mature fruits.

The effect of plant fiber addition to the formulation on the acidity of fruit snacks can be seen in Table 2. In general, the titratable acidity values of fruit snacks vary between 0.64% and 0.72%, and the addition of dietary fiber to fruit snacks has resulted in a reduction in acidity ($p<0.05$). An increase in pH values is observed to correspond with a decrease in acidity values in the samples. While the acidity values of the control and I-1 samples were found to be similar ($p>0.05$), an increase in inulin content to 5% (I-2) led to a significant reduction in acidity ($p<0.05$). Additionally, the acidity values of the control sample and CF-1 sample were found to be statistically different ($p<0.05$). It can be considered that the reason for fruit snacks enriched with carrot fiber having the lowest acidity values compared to other samples may be due to the pH of the added carrot fiber being approximately between 5 and 5.5 in the formulation. A study reported by Akhtar et al. [14], the titratable acidity of fruit bar produced by date and apple pulp as citric acid equivalent was found to be 0.41-0.52%. In another study on guava and orange fruit bar, the titratable acidity varied between 0.32 and 0.64% [19]. It was also reported that high acidity present in fruits serves a dual function by inhibiting the growth of microorganisms and supporting the preservation of the fruit's color and flavor [19].

Table 2. pH, water activity, acidity, and total phenolic content of fiber-enriched fruit snacks

Sample code	pH	Water activity	Titratable acidity (%)	Total phenolic content (mg GAE/100 g)
C	4.86±0.01^{e}	0.69±0.01^{a}	0.72±0.01^{ab}	595.1±9.5^{ab}
I-1	4.90±0.01^{d}	0.66±0.02^{b}	0.70±0.02^{bc}	583.5±4.8^{abc}
I-2	4.95±0.02^{bc}	0.64±0.00^{bc}	0.68±0.02^{cd}	571.9±10.6^{c}
PF-1	4.84±0.01^{e}	0.65±0.01^{bc}	0.73±0.01^{a}	581.0±13.5^{bc}
PF-2	4.93±0.01^{cd}	0.63±0.02^{cd}	0.69±0.01^{c}	566.9±7.6^{c}
CF-1	5.04±0.02^{a}	0.63±0.00^{cd}	0.64±0.02^{e}	597.3±5.8^{ab}
CF-2	4.98±0.03^{b}	0.61±0.01^{d}	0.66±0.00^{de}	601.4±12.3^{a}

$^{a-e}$ Different letters in same column indicates significant difference between the groups ($p<0.05$).

Dried fruits are globally recognized as essential nutritious snacks, representing a condensed version of fresh fruits with reduced water content. Common examples of traditional dried fruits, without added sugars, include apples, apricots, dates, figs, mulberries, peaches, pears, prunes, and raisins. The quantity of polyphenolic compounds found in these fruits is influenced by factors such as the fruit variety, environmental factors (such as soil quality, fertilization, temperature, and cultivation methods), storage and transportation conditions, as well as the specific processing techniques employed [20, 21].

The total phenolic content of fruit snacks was given in Table 2, and ranging from 566.9 to 601.4 mg GAE/100 g. The total phenolic content of samples I-1, CF-1, and CF-2 was found to be similar to that of the control group ($P>0.05$). However, samples I-2 and PF-2 exhibited a significantly lower total phenolic content compared to the other samples ($p<0.05$). The total phenolic content of dried apricots and dates were reported as 549 mg GAE/100 g and 661 mg GAE/100 g, respectively [22, 23]. In this study, in order to make a meaningful the comparison of the obtained results with the literature, a mixture of apricot and date at a ratio of 50:50 (w/w) was considered, resulting in a total phenolic content of 605 mg/100 g. Therefore, the obtained results were found to be in accordance with the literature [22, 23]. In another study, it was reported that the total phenolic content of fruit bar produced date paste was 224.3-240.3 mg GAE/100 g [24].

The composition and energy values of all fruit snacks were presented in Table 3. Moisture content of samples were changed between 22.8 to 23.8%, higher moisture level was observed for fiber enriched snacks compared to the control group ($p<0.05$). The moisture contents of fruit snack samples I-1 and CF-1 were found to be similar ($p>0.05$), and there was also no statistically significant difference found between the samples of I-2

and CF-2 (p>0.05). According to Parn et al. [24], the moisture content of fruit bar produced by date paste varied between 24.5 to 26.3. Moreover, it was reported that the moisture content of freshly prepared date paste was 19.12% [17]. In another study by Sharma et al. [25], the moisture content of apricot bar was 18.9-20.9%. In addition, it was determined that the moisture content of dried dates and apricots were 25% and 35%, respectively [26].

Table 3. General composition and energy values of fiber-enriched fruit snacks

Sample code	Moisture (%)	Ash (%)	Total fat (%)	Protein (%)	Carbohydrate (%)	Total dietary fiber (%)	Energy (kcal/100 g)
C	23.8±0.10^{a}	5.60±0.12^{b}	0.65±0.13^{a}	2.90±0.10^{de}	60.3±0.45^{a}	6.8±0.05^{e}	258.5±0.43^{ab}
I-1	23.3±0.02^{c}	5.62±0.07^{b}	0.69±0.05^{a}	2.68±0.04^{f}	58.9±0.14^{c}	8.8±0.04^{b}	252.6±0.11^{c}
I-2	22.8±0.04^{e}	5.63±0.02^{b}	0.68±0.02^{a}	2.80±0.02^{e}	57.3±0.07^{d}	10.8±0.06^{a}	246.5±0.38^{d}
PF-1	23.4±0.05^{b}	5.70±0.10^{ab}	0.70±0.01^{a}	3.30±0.10^{b}	59.7±0.19^{b}	7.2±0.01^{d}	258.3±0.31^{ab}
PF-2	23.1±0.01^{d}	5.60±0.05^{b}	0.68±0.05^{a}	3.84±0.05^{a}	59.1±0.02^{c}	7.7±0.08^{c}	257.8±0.73^{b}
CF-1	23.3±0.04^{c}	5.70±0.10^{ab}	0.71±0.03^{a}	3.00±0.04^{d}	60.1±0.18^{ab}	7.2±0.10^{d}	258.6±0.41^{a}
CF-2	22.8±0.06^{e}	5.81±0.02^{a}	0.73±0.02^{a}	3.15±0.01^{c}	59.9±0.08^{ab}	7.6±0.02^{c}	258.8±0.46^{a}

$^{a-f}$ Different letters in same column indicates significant difference between the groups (p<0.05).

Results of the ash contents of fruit snacks, which represents the overall mineral content, were ranged between 5.60 and 5.81% (Table 3). There was no significant difference observed for the ash content of fruit snacks except for CF-2. As a result, addition of plant fiber did not affect the total ash content of fruit snacks significantly compared to the control group. A study on vegetable dietary fiber concentrates, the ash content of carrot fiber was found to be 5.03% [6]. It was reported that dried fruits had 2.4-3.5% of total ash content [27]. Moreover, a study on apricot snack bar including 69.4% of apricot paste and 30.6% of other ingredients (corn flour, skim milk, almond, pistachio, coconut powder, chickpea, and brown sugar) reported the total ash content as 3.08% [28]. Furthermore, the ash content of cereal bar including oat flakes, dried fruits (grapes, apricots), nuts, butter, glycerol and honey was 1.35-1.51% [3].

The total fat content of control group and fiber enriched fruit snacks were determined in the range of 0.65-0.73%. There was no statistically significant difference observed between the groups (p>0.05). In a study by Singh et al. [17] reported the total fat content of date paste was 0.76%. In another study by Drougoudi et al. [29] found that the dried apricot had 3.39 g of protein, 2.57g of ash, 0.51g of fat per 100 g of fruit. In addition, it was determined that the fat content of dried dates and apricots were 0.17% and 0.33-1.20%, respectively [26].

The protein content of fruit snacks was presented in Table 3. The protein content of control group was 2.90%, and fiber enriched fruit snacks had the protein between the range of 2.68-3.84%. While the total protein content of I-1 was the lowest, PF-2 showed the highest protein content. I-1 and CF-1 had similar protein content with control group (p>0.05), and the other snacks were found to be statistically different (p<0.05). Although the protein content of samples I-1 and CF-1 is similar to that of the control group (p>0.05), the protein contents of other fruit snacks were found to be statistically different from the control group (p<0.05). In a study by Singh et al. [17] determined that date paste had 1.75% of protein. Another study by Munir et al. [16] reported that the protein content of date paste was 2.38%. In addition, the protein content of date bars prepared by different varieties of date fruit was found to be 2.22-4.06% [24]. Moreover, the protein content of carrot fiber was determined as 6.73% [6]. Furthermore, the protein content of date bar was found to be 1.90% [17]. In a study, the protein content of cereal bar including oat flakes, dried fruits (grapes, apricots), nuts, butter, glycerol and honey was 8.64% [3]. In addition, it was determined that the protein content of dried dates and apricots were 1.8-2.5% and 2.5%, respectively [26].

The carbohydrate content of fruit snacks was shown in Table 3, ranging from 57.3 and 60.3%. The lowest carbohydrate content was determined in I-2 and the highest carbohydrate was observed in control group. PF-1, CF-1, and CF-2 had similar total carbohydrate content with control group (p>0.05). In addition, there is no significant differences found in the carbohydrate content of I-1 and PF-2 (p>0.05). Compared to the control, the carbohydrate content of fruit snacks enriched with inulin and pea fiber was found to be different (p<0.05). In a study reported by Parn et al. determined the carbohydrate content of date bar produced by different varieties of date fruit as 56.8-72.65% [24]. Moreover, it was reported that the total carbohydrate of dried apricots was 62.6% [29]. Another study reported by Munir et al. [28], total carbohydrate content of apricot bar was found to be 67.3%. In addition, it was determined that the carbohydrate content of dried dates and apricots were 67.5% and 62.5%, respectively [26]. Obtained results from this study was in line with the previous literature research.

Total dietary fiber content of control group (without plant fiber addition) was found as 6.8%, indicating that apricot and date paste (1:1, w/w) had good source of fiber content as expected. The total dietary fiber content of fruit snacks enriched with plant fibers ranged from 7.2% to 10.8%. In comparison to the control group, the total dietary fiber content of all fruit snacks was found to be statistically different (p<0.05). The total fiber content of PF-2 and CF-2 samples was found to be similar (p<0.05). Furthermore, there was no significant difference in fiber content between PF-1 and CF-1 samples (p>0.05). Among all samples, the highest fiber content was observed in sample I-2. According to the Turkish Food Codex & the Regulation on Nutrition and Health Claims, since the formulated fruit snacks contain more than 6 grams of total dietary fiber per 100 grams, it

can be labeled as 'high in fiber' or 'excellent source of fiber' on the packaging.

In a study by Singh et al. [17] determined that date paste had 2.30% of crude fiber. In addition, it was reported that apricot-based snack bar had the fiber content as 8.33% [28]. In another study by Munir et al. [16], total fiber content of date-based snack bar determined as 2.9%. Moreover, the total fiber content of date bars were found to be 4.5-5.6% [24]. In another study, total fiber content of fruit-based functional snack bars was 2.54-5.42% [15]. It was reported that dried dates and apricots had 7.5% of dietary fibers [26].

The energy values of fruit snacks range from 246.5 to 258.8 kcal/100 g (Table 3), and the energy value for the control group has been determined as 258.5 kcal/100 g. The lowest calorie value was calculated in sample I-2, while the highest calorie value was observed in sample CF-2. While the energy values of samples C, PF-1, CF-1, and CF-2 were found to be similar to each other ($P>0.05$), the energy values of samples I-1 and I-2 were found to be statistically different ($p<0.05$). In a study on nutritional composition on dried fruits, the energy values of date and dried apricot were found as 300 kcal/100 g and 250 kcal/100 g [26].

Table 4. Texture of fiber-enriched fruit snacks

Sample code	Hardness (g)	Adhesiveness (g*sec)	Cohesiveness	Gumminess	Chewiness
C	4000.3±115^{b}	-162.04±87.6^{b}	0.29±0.05^{c}	1153.4±21.1^{bc}	544.07±12.1^{de}
I-1	2530.8±29^{g}	-1041.1±21.3^{e}	0.42±0.04^{ab}	1059.2±15.9^{c}	741.9±17.5^{c}
I-2	3040.4±58.2^{e}	-86.6±31.8^{a}	0.44±0.01^{a}	1322.8±25.9^{b}	781.8±18.6^{c}
PF-1	2671.9±25.3^{f}	-678.3±14.4^{d}	0.38±0.02^{b}	1035.2±129.2^{c}	591.5±88.25^{d}
PF-2	3798.3±40.9^{c}	-116.4±15.5^{ab}	0.45±0.01^{a}	1739.4±210.2^{a}	1148.85±31.5^{a}
CF-1	3527.4±38.5^{d}	-268.6±11.3^{c}	0.31±0.02^{c}	1100.4±109.8^{c}	480.9±42.7^{e}
CF-2	4322.2±37.7^{a}	-131.1±17.0^{ab}	0.40±0.01^{ab}	1753.55±14.3^{a}	1001.1±10.45^{b}

$^{a-g}$ Different letters in same column indicates significant difference between the groups ($p<0.05$).

The texture of a product plays a crucial role in influencing consumers' willingness to embrace a new offering. Textural properties of fruit snacks enriched with different fibers (hardness, adhesiveness, cohesiveness, gumminess, and chewiness) are presented in Table 4. Among the textural parameters, hardness is a key parameter to effect consumer acceptability of fruit snacks [16]. In this study, minimum hardness was measured for I-1, while maximum value was observed for CF-2. Compared to control group, the addition of dietary fiber was significantly increased the hardness values of fruit snacks ($p<0.05$). The adhesiveness values of the samples range from -86.6 to -1041.1 g*sec. Samples I-2, PF-2, and CF-2 exhibited similar adhesiveness values ($P>0.05$). Overall, it is observed that the addition of 5% fiber to the samples resulted in a decrease in adhesiveness values. The cohesiveness values of fruit snacks range from 0.29 to 0.45, and the cohesiveness values of samples I-1, I-2, PF-2, and CF-2 were found to be similar ($p>0.05$). The gumminess values of the samples vary between 1035.2 and 1753.6, with the gumminess value of the control sample being 1153.5. In groups where 2.5% fiber was added, the gumminess value decreased compared to the control group, while in groups where 5% fiber was added, the gumminess value increased. The gumminess values of samples I-1, PF-1, and CF-1 were found to be similar to the control group ($p>0.05$). The chewiness values of the samples range from 480.9 to 1148.9, with the control group having a chewiness value of 544.1. There was no statistically significant difference in chewiness values between samples I-1 and I-2, with the highest chewiness value observed in sample PF-1. A study reported that the hardness, adhesiveness, cohesiveness, gumminess and chewiness values of fruit bar produced by date paste were 1572-2189, -733.8-793.9, 0.36-0.61, 836.5-1334.6, 772.90-1319.1 g/s, respectively [24]. Furthermore, it was reported that hardening of fruit bars after the addition of dietary fiber may be linked to the transfer of water between the carbohydrate and the protein components. Carbohydrate ingredients, such as dietary fibers added for moisture retention and texture modification, could effectively prevent moisture loss to the surrounding environment [15].

Color is the most important parameter affecting consumer acceptability of snack foods. The color parameters (L*, a*, and b*), color difference compared to control group, and Chroma values were shown in Table 5. The L* values of fruit snacks range from 23.1 to 34.1, the a* values range from 9.7 to 12.3, and the b* values range from 14.6 to 19.6. It was observed that when the dietary fiber content was increased for all groups, L* values also increased while a* decreased ($p<0.05$). In addition, the L* values of fiber-enriched fruit snacks increased with increasing concentration of dietary fibers from 2.5 to 5%. Considering the a* value, the addition of 2.5% of carrot fiber to the snack formulation was found similar to control group which has no fiber enrichment ($p>0.05$). b* values of samples were found significantly different for fiber-enriched fruit snacks except for PF-1.

Color difference (ΔE^{*}) values were calculated as 5.73-11.31 (Table 5). ΔE^{*} values below 1 suggest that color variances were not easily detectable by the human eye. When ΔE^{*} falls between 1 and 3, the differences in color were not readily noticeable to human perception. On the other hand, when ΔE^{*} surpasses 3, it indicates distinct and easily recognizable color differences as perceived by the human eye [30]. In this study, ΔE^{*} values were found as >5 meaning that the addition of 2.5 and 5% of fiber to the formulation of fruit snacks changed the color and this change was easily noticeable. These results showed that color changes occur in the preparation of fruit snacks, and addition of different type of fiber might have contributed to the observed color changes. Chroma (C*) indicates the intensity of color with ranging from 0 to 100, which is considered as a quantitative

measure of color [31]. Chroma (C*) values of fruit snacks were given in Table 5, ranging between 17.53 to 22.10. The C* values of CF-1 was similar to control group (p>0.05), while the highest color intensity was observed in CF-2. As stated by Sharma, a primary factor in determining color differences is attributed to lightness, and due to the reduced sensitivity of human eyes to changes in both lightness and chroma [32]. In other words, a small C* can be easier to differentiate than a high ΔE* [32]. In a study by Parn et al., the color values of date bar were determined as L* of 40.37-43.89, a* of 9.85-12.15, and b* of 29.03-30.45 [24].

Table 5. Color values of fiber-enriched fruit snacks

Samples	L*	a*	b*	Color difference (ΔE*)	Chroma (C*)
C	23.1±1.10^{e}	12.3±1.06^{a}	16.5±1.24^{c}	-	20.62±0.36^{b}
I-1	28.2±0.60^{d}	10.5±1.28^{bc}	15.1±0.62^{d}	5.73±0.12^{d}	18.40±1.24^{cd}
I-2	30.3±0.45^{bc}	9.7±0.08^{c}	14.6±0.04^{d}	7.89±0.45^{b}	17.53±0.08^{d}
PF-1	31.5±0.09^{b}	11.2±1.02^{abc}	15.8±0.06^{cd}	8.54±0.06^{b}	19.38±0.64^{c}
PF-2	34.1±0.04^{a}	10.4±0.06^{bc}	14.9±1.05^{d}	11.31±0.10^{a}	18.18±0.83^{cd}
CF-1	29.5±1.12^{c}	11.6±1.34^{ab}	18.4±0.15^{b}	6.83±0.87^{c}	21.77±0.59^{ab}
CF-2	30.7±0.03^{bc}	10.2±0.05^{bc}	19.6±0.05^{a}	8.47±0.04^{b}	22.10±0.07^{a}

$^{a-e}$ Different letters in same column indicates significant difference between the groups (p<0.05).

Table 6. Total aerobic mesophilic bacteria (TAMB), yeast and mold counts of fiber-enriched fruit snacks

Samples	TAMB (log CFU/g)	Yeast and Mold (log CFU/g)
C	3.32^{d}	1.96^{c}
I-1	3.30^{e}	2.05^{b}
I-2	3.37^{c}	1.97^{c}
PF-1	3.24^{g}	2.08^{b}
PF-2	3.28^{f}	2.13^{a}
CF-1	3.47^{b}	2.16^{a}
CF-2	3.48^{a}	2.08^{b}

$^{a-g}$ Different letters in same column indicates significant difference between the groups (p<0.05).

Table 6 indicates the total aerobic mesophilic bacteria (TAMB) and yeast & mold counts (YM) of control and fiber-enriched fruit snacks. The TAMB and YM counts of control group were 3.32 and 1.96 log CFU/g, respectively. The TAMB of fruit snacks were found between 3.24 to 3.48 log CFU/g and there were significant differences observed as the type of fiber changed in the formulation of fruit snack (P<0.05). In terms of YM counts, I-2 sample was similar to control group (P>0.05). In addition, there was no statistically important differences found in I-1, PF-1, and CF-2 (P>0.05). According to the Turkish Food Codex Microbiological Criteria Regulation, only mold and yeast counts (n:5, c:2, m: 10^4, M: 10^5) are considered as criteria for dried fruits. In this study, all analyzed samples of fruit snacks fall within the acceptable limits defined by the Turkish Food Codex Microbiological Criteria Regulation [33] in terms of mold and yeast counts.

The effect of addition of different plant fibers on the sensory properties of fruit snacks is presented in Table 7. When the odor values of the samples were considered, scores between 4 and 6.2 were obtained, and all samples except CF-2 showed similar characteristics to the control group (p>0.05). In terms of color evaluation of the fruit snacks, scores ranging from 4.9 to 6.55 were obtained, and all samples except CF-1 and CF-2 exhibited similar characteristics to the control group (p>0.05). The flavor values of the samples ranged from 3.90 to 6, with the control sample being the most liked and CF-2 being the least liked. The textural properties of the samples were found to be similar (p>0.05), except for CF-2, with CF-2 being the least liked in terms of texture. Appearance values for the samples were scored between 4.75 and 6.55, with sample I-1 being the most preferred. Except for CF-2, all other samples were statistically similar to the control group. The overall acceptability values of the samples ranged from 4.15 to 6.55, and the fruit snacks enriched with inulin and pea fiber showed similar overall acceptability to the control group (p>0.05). The lowest overall acceptability value was observed in the CF-2 sample (p<0.05). The FACT values of the samples ranged from 3.80 to 6.40, and the samples enriched with inulin and pea fiber exhibited similar characteristics to the control group (p>0.05). According to the sensory analysis results, the consumer acceptability of fruit snacks enriched with carrot fiber was found to be low.

Numerous research studies support the notion that increasing dietary fiber intake enhances feelings of satiety, reduces hunger, and promotes a sense of satisfaction. Foods rich in dietary fiber often have a high volume and a low calorie density, contributing to a sense of fullness and playing a role in regulating energy balance [34]. In the future, there is an expectation that research will persist in exploring the health impacts of industrially or functionally improved foods rich in dietary fiber. It is anticipated that irrespective of dietary preferences, these foods will assume a more significant position in the dietary patterns of numerous individuals [35]. Thus, it is important to produce high in fiber fruit snacks with high quality and consumer acceptability for daily diet.

Table 7. Sensory properties* of fiber-enriched fruit snacks

Sample code	Odor	Color	Flavor	Texture	Appearance	Overall acceptance	FACT
C	6.20±0.89^{a}	6.55±0.60^{a}	6.00±0.65^{a}	6.35±0.59^{a}	6.40±0.68^{a}	6.55±0.60^{a}	6.40±0.50^{a}
I-1	5.95±1.05^{a}	6.40±0.60^{a}	5.70±0.57^{a}	6.45±0.51^{a}	6.55±0.60^{a}	6.45±0.51^{a}	6.50±0.51^{a}
I-2	5.85±0.90^{a}	6.10±0.72^{a}	5.80±0.62^{a}	6.35±0.49^{a}	6.35±0.75^{a}	6.31±0.74^{a}	6.42±0.60^{a}
PF-1	5.65±0.88^{a}	6.20±0.62^{a}	5.55±0.76^{ab}	6.20±0.52^{a}	6.10±0.72^{a}	6.25±0.79^{a}	6.35±0.49^{a}
PF-2	5.55±0.83^{ab}	6.25±0.55^{a}	5.00±0.97^{abc}	5.90±0.55^{a}	6.15±0.67^{a}	5.75±0.72^{ab}	6.05±0.60^{a}
CF-1	5.30±0.73^{ab}	5.45±0.50^{b}	4.30±0.73^{bc}	5.75±0.55^{a}	5.30±0.57^{ab}	4.90±0.45^{bc}	4.50±0.69^{b}
CF-2	4.00±0.79^{b}	4.90±0.65^{c}	3.90±0.72^{c}	3.95±0.76^{b}	4.75±0.72^{b}	4.15±0.67^{c}	3.80±0.41^{b}

*: 1-point for least undesirable and 7-point indicating for the most desirable. $^{a-c}$: Different letters in same column indicates significant difference between the groups ($p<0.05$).

CONCLUSION

The enrichment of fruit snacks with dietary fiber holds significant importance in promoting overall health and well-being. Fiber is an essential component of a balanced diet, playing a crucial role in maintaining digestive health and regulating blood sugar levels. Incorporating fiber into fruit snacks not only enhances their nutritional value but also contributes to satiety, helping individuals feel fuller for longer periods. In this study, fruit snack formulations based on dates and apricots were enriched with different plant-based dietary fibers (inulin, pea, and carrot fiber) at 2.5% and 5.0% ratios, and the changes in quality attributes and consumer acceptability were investigated. The addition of plant fiber to the formulation resulted in a decrease in the acidity and moisture contents of the fruit snacks compared to the control. All samples had a dietary fiber content of >6 g/100 g, allowing them to be labeled as "high in fiber" on the packaging. When the added fiber content was increased from 2.5% to 5.0%, it was determined that the hardness, gumminess, and chewiness values of the fruit snacks increased. Moreover, the addition of fiber significantly affected the color difference of the fruit snacks compared to the control. All produced fruit snacks were found to be microbiologically safe. Fruit snacks enriched with inulin and pea fiber were well-liked by the panelists in terms of sensory attributes, and their consumer acceptability was higher than the fruit snacks enriched by carrot fiber. It is recommended that future studies focus on developing high-nutrient and highly consumer-accepted fruit snack formulations using different plant fiber sources, investigation of quality changes during storage, and conducting *in vitro* digestibility studies of fiber-enriched fruit snacks.

CONFLICT OF INTEREST

The author declared no conflict of interest.

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