Original Research Article

Optimization of Fruit Bar Formulation: A Comprehensive Study on Physicochemical and Sensory Properties

Abstract

Fruit bars are a convenient snack choice that offers the health advantages of fruits and has a considerably higher nutritional value than fresh fruits. The study aimed to develop three fruit bar (FB) variants using different ingredients. FB1 - dried apricot + dried sapota; FB2 - dried banana + dried mango; FB3 - dried apricot + dried sapota + dried banana + dried mango, and with other ingredients respectively. The proximate (moisture, ash, total protein, crude fat, crude fiber, CHO), mineral (iron, calcium, sodium, potassium), phytochemical (TPC, TF, tannin), antioxidant (DPPH, vitamin C), physical properties (a_w, texture), sensory evaluation, and cost estimation of all three variants of formulated FB were analyzed. The data were analyzed by mean±standard deviation and one-way ANOVA test. The results suggested that FB2 and FB3 had better proximate and mineral analysis. However, TPC and TF were observed to be the highest in FB1 and the other highest phytochemical in FB3. The lowest a_w was found in FB2 and texture-wise items exhibited the lowest hardness in FB3 and fractureability in FB2 variant, suggesting a simple to bite and chew nature. The cost of formulated fruit bar variants was between Rs. 50-60 per 100 g, which was less than the market yoga bar. According to the mean values for sensory evaluation, FB3 was more acceptable than other variants. Hence, based on the results obtained in this study, it may be concluded that the developed FB2 and FB3 would be more acceptable and nutritious regarding proximate, mineral, and phytochemical potential.

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Keywords: Easy-to-use; fruit; handy; nutritious; snacks.

1. INTRODUCTION

Fruits provide abundant energy, fiber, minerals, and vitamins, making them essential for a nourishing and balanced diet (Orrego et al., 2014). Fruits are processed to create a range of shelf-stable goods and concentrates, including jams, smoothies, squashes, and juices. Another way to preserve fruits is by processing them into dehydrated forms like fruit leathers/sheets and fruit bars. This is one of the latest technologies used in fruit preservation (Arinzechukwu and Nkama, 2019).

Fruit bars are a healthy and tasty substitute for snack foods since they are high in nutrients. Fruit bars are made by freezing different nuts with different dried fruits in honey or sugar syrup. A fruit bar, made from dried fruits, is a convenient way to eat fruit when it's not in season. It also has a concentrated nutritional value. Fruit bars are produced differently by various companies using different formulas and procedures (Eyiz et al., 2020).

Apricot (*Prunus armeniaca* L.) belongs to the family Rosaceae. People adore apricots because of their delicious flavor, enticing perfume, vivid colors, and health advantages. Numerous bioactive substances, such as carotenoids, polyphenols, high-oleic lipids, reductive sugars, triacylglycerols, squalene, phytosterols, tocols, volatiles, polysaccharides, pectins, fatty acids, minerals, vitamins, and dietary fibers, as well as specific amounts of starches, and proteins, are present in apricot fruit, which contributes to its appearance, and dietary value. It was found that the main carotenoid molecule in apricots is β-carotene, which is the main precursor of provitamin A and has been connected to several health benefits (Chaudhary et al., 2024).

Sapota (*Manilkara zapota* L.) belongs to the family Sapotaceae. Due to its abundance of beneficial nutrients, sapota is a notable little fruit crop and might be considered one of the

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Complete your introduction by addressing the following key points:

1. Provide a brief overview of the current understanding of the topic under investigation.
2. Clearly articulate the research gap or problem that the study aims to address.
3. State the specific goals or objectives the researcher seeks to achieve in the study.
4. Present the thesis statement, outlining the main argument or position of the paper.
5. Highlight the significance or contribution of the study to the relevant discipline.

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healthiest fruits. This delicious fruit has a granular texture, an appealing odor, and a mellow and sweet flesh. It contains many phytochemicals, polyamines, fatty acids, glucose, fructose, sucrose, dietary fiber, minerals, and vitamins. The amino acids that are added to sapota fruit include taurine, tyrosine, threonine, serine, valine, phosphoethanolamine, glutamic acid, glycine, methionine, proline, hydroxyproline, and phenylalanine. The sapota fruit extract contains 24 antioxidant components, including glycosides, terpenes, polyphenols, and flavonoids (Chaudhary et al., 2023).

Banana (*Musa sapientum*) belongs to the family Musaceae. With its high nutritional content, it helps numerous nutrients be better absorbed while absorbing the least amount of fat. They may even improve the performance of endurance exercises and aid in the maintenance of plasma glucose levels. It has unsaturated fatty acids and sterols, among other phytochemicals. It is also regarded as a very good source of vitamins, minerals, and fiber. Bananas, like other important fruits, are rich in bioactive chemicals, such as carotenoids, flavonoids, phenolics, amines, vitamins C and E, and phenolics. These molecules have antioxidant properties and can be very beneficial to human health (Kumari, 2023).

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Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae. Its nutritional significance and abundance of many phytochemicals with a range of functions make it one of the most significant fruits in the world. In addition to being high in non-nutrient substances like organic acids, and dietary fiber. It is also high in nutrients including carbohydrates, fatty acids, and minerals. The most prevalent bioactive substances found in mango fruit are carotenoids, polyphenols (anthocyanins, tannins, mangiferin, quercetin, catechins, kaempferol, gallic acid, and ellagic acid), phenolic acids (ferulic acid, coumaric acid, and hydroxybenzoic acid), and vitamins (ascorbic acid, thiamine, riboflavin, and niacin). It has been claimed that these substances have antioxidant action and help to prevent a variety of ailments (Yahia et al., 2023).

The current study was designed to develop ready-to-eat fruit bars utilizing nutrient- and antioxidant-rich components in line with the ongoing conversation. The nutritional and sensory qualities of the formulated fruit bars were then examined in more detail.

2. MATERIALS AND METHODS

2.1 Collection of Ingredients

The different ingredients such as figs, dates, raisins, pumpkin seeds, muskmelon seeds, coconut powder, cardamom, jaggery, and ghee were obtained from the market of Banasthali Vidyapith, Rajasthan. The other dried apricots, dried bananas, dried mango, dried sapota, and instant rolled oats were ordered online from the Amazon application.

2.2 Preparation of Fruit Bar

The fruit bar was prepared according to the method described by Chaudhary et al., (2022). The three variants of fruit bars (FB1, FB2, FB3) were formulated by using various ingredients in different amounts, as shown in Table 1. These were prepared in the Cooking Laboratory of the Department of Food Science and Nutrition of Banasthali Vidyapith, Rajasthan, as shown in Fig. 1.

Table 1: Raw Ingredients of Formulated Fruit Bar

Ingredients (100 g)	FB1	FB2	FB3
Dried Apricot (g)	18	-	5
Dried Banana (g)	-	14	15
Dried Mango (g)	-	20	10
Dried Sapota (g)	15	-	10
Figs (g)	4	2	2
Dates (g)	5	4	5
Raisins (g)	5	5	5
Instant Rolled Oats (g)	12	15	10
Pumpkin Seeds (g)	10	10	8
Muskmelon Seeds (g)	8	8	10
Coconut Powder (g)	4	4	2

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Cardamom (g)	1	1	1
Jaggery (g)	10	10	12
Ghee (ml)	8	6	5

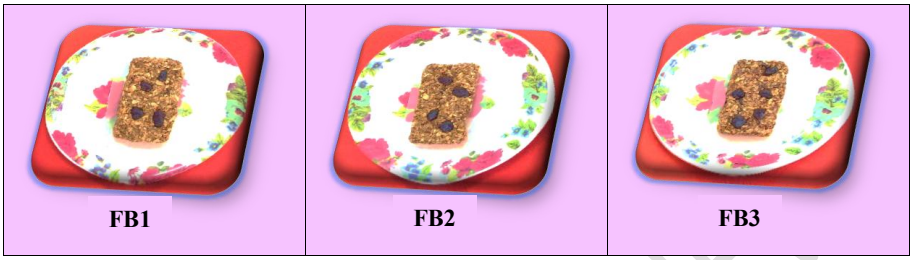

Fig. 1: Formulated Fruit Bar

2.3 Proximate and Mineral Analysis

A moisture analyzer (Air oven) was used to detect the fruit bar's moisture content. The ash level was detected after six hours in the muffle furnace at 550° C. By implementing the Kjeldahl method, the total protein content was determined. The crude fat was calculated using the Soxhlet apparatus. The crude fiber was estimated with the use of an acid and alkali treatment process. The overall amounts of moisture, ash, protein, crude fat, and crude fiber were reduced from 100 to determine the number of carbohydrates (CHO), which was then used to compare the approximate composition of the fruit bar. Wong's technique for iron, the titrimetric method for calcium, and other sodium and potassium were used to assess the mineral content of the fruit bar (Sharma, 2007; Raghuramulu et al., 2003).

2.4 Phytochemical and Antioxidant Activity

The Folin-Ciocalteau technique was used to determine the total phenolic compounds (TPC) in the fruit bar (Bettaieb et al., 2010). The content of total flavonoids (TF) and tannin was assay described by Bettaieb et al., (2010). Colorimetric analysis was used to measure the antioxidant activity as DPPH radical scavenging activity using 2, 2-diphenylpicrylhydrazyl (DPPH)

radicals (Bettaieb et al., 2010) and vitamin C by the titrimetric method (Raghuramulu et al., 2003).

2.5 Physical Properties

Water Activity (a_w) in fruit bar was examined using the methodology outlined by Nadeem et al., (2011). Utilizing a texture analyzer with a 5-kg load cell, the texture analysis of the fruit bar was determined using the methodology outlined by Nadeem et al., (2012). Instrumental texture analysis noted two characteristics, such as hardness and fractureability.

2.6 Sensory Evaluation

As part of the sensory evaluation, a group of specialists assesses the fruit bar' quality. Measurement, examination, as well as evaluation of the characteristics of the bar as experienced by taste, smell, touch, and hearing are all part of the rating process. A panel of 25 semi-trained members was selected by using the triangle difference test. Using the 9-point hedonic scale performa, the fruit bar's acceptability is determined. Some attributes were looked at appearance, color, texture, odor, taste, mouthfeel, and overall acceptability. At Banasthali Vidyapith, Rajasthan, in the Department of Food Science and Nutrition, sensory tests were carried out (Chaudhary et al., 2023).

2.7 Statistical Analysis

The data was statistically processed using the IBM SPSS Statistics software program. The results were expressed as mean±standard deviation (SD) of the triplicate determinations. The significance threshold of 5% probability level ($P<0.05$) is determined by comparing means and looking at variations in all the assessments of developing fruit bar variants using the One-Way Analysis of Variance (ANOVA) test.

2.8 Cost Estimation

The cost estimation of the formulated fruit bar was done to compare it with the options available in the market.

3. RESULTS AND DISCUSSION

3.1 Proximate and Mineral Analysis

The results of the proximate and mineral analysis of the formulated fruit bar are shown in Table 2. The different base ingredients in all three variants of the formulated fruit bar may be the reason behind the different ratios of proximate and mineral and also demonstrate significant differences ($P<0.05$) across multiple parameters, highlighting the impact of ingredient composition on overall nutrient density. The proximate and mineral analysis of the formulated fruit bars (FB1, FB2, FB3) provides crucial insights into their nutritional composition, potential health benefits, and shelf stability.

Table 2: Proximate and Mineral Analysis of Formulated Fruit Bar

Proximate Analysis (g/100 g)	**FB1**	**FB2**	**FB3**
Moisture	5.4 ± 0.01^{s}	5.2 ± 0.02^{s}	6.8 ± 0.01^{s}
Ash	3.2 ± 0.01^{s}	3.3 ± 0.01^{s}	4.4 ± 0.03^{s}
Total Protein	10.1 ± 0.05^{s}	10.4 ± 0.01^{s}	10.5 ± 0.03^{s}
Crude Fat	18.2 ± 0.02^{s}	17.2 ± 0.04^{s}	17.5 ± 0.01^{s}
Crude Fiber	5.2 ± 0.02^{s}	5.2 ± 0.01^{s}	5.3 ± 0.02^{s}
CHO	57.9 ± 0.03^{s}	58.7 ± 0.03^{s}	55.5 ± 0.5^{s}
Mineral Analysis (mg/100 g)	**FB1**	**FB2**	**FB3**
Iron	10.6 ± 0.05^{s}	10.0 ± 0.01^{s}	10.7 ± 0.02^{s}
Calcium	92.3 ± 0.03^{s}	95.5 ± 0.02^{s}	93.6 ± 0.03^{s}
Sodium	20.1 ± 0.02^{ns}	24.2 ± 0.01^{ns}	22.0 ± 0.01^{ns}
Potassium	31.5 ± 0.01^{ns}	34.1 ± 0.3^{ns}	36.4 ± 0.05^{ns}
Values are expressed as mean±SD, n=3. Values followed by ^{s} are a significant difference ($P<0.05$) and ^{ns} are not a significant difference ($P>0.05$)			

The moisture content of the fruit bars ranged from 5.2% (FB2) to 6.8% (FB3). The significantly ($P<0.05$) higher moisture content in FB3 suggests a potential impact on shelf life, as higher

moisture levels increase microbial susceptibility. This variation can be attributed to the higher proportion of dried banana, mango, and sapota, which retain more moisture. Lower moisture in FB1 and FB2 (5.2% - 5.4%) indicates better storage stability and reduced chances of microbial spoilage (Norouzian et al., 2024; Ojurongbe et al., 2022). The ash content, indicative of total mineral presence, was significantly ($P<0.05$) highest in FB3 (4.4%) and lowest in FB1 (3.2%). The significant difference among formulations suggests that FB3 had a richer mineral profile, possibly due to its varied ingredient composition. Similar trends were observed in the development of a strawberry bar, where variations in ingredient composition led to differences in ash content (Akter et al., 2023). The total protein content varied slightly among formulations, with FB3 containing slightly the highest (10.5%), while FB1 and FB2 had 10.1% and 10.4%, respectively. The inclusion of ingredients like pumpkin seeds, muskmelon seeds, and oats contributed to the protein content. This aligns with research indicating that incorporating certain plant-based ingredients can enhance the protein content of snack bars (Hertzler et al., 2020). The crude fat content ranged from 17.2% (FB2) to 18.2% (FB1). The slight variation can be linked to differences in the proportion of seeds and oats, which are primary sources of healthy fats. Studies have shown that the type and amount of seeds used in snack bars can influence their fat content (Alfheeaid et al., 2023). Dietary fiber plays a crucial role in digestive health, and all formulations contained significant amounts (5.2% - 5.3%). These values were consistent with fruit-based bars containing fiber-rich ingredients. This aligns with research indicating the similar finding of fiber in snack-based bar (Sun-Waterhouse et al., 2010). The CHO content was highest in FB1 (57.9%) and FB2 (58.7%), whereas FB3 had a lower value (55.5%). CHO serves as a primary energy source, and their adequate presence in the fruit bars ensures sustained energy release. The primary component of fruit bars is primarily sourced from fruits and sweeteners, all contributing to natural sugars and energy availability. Similar results on snack bars with African breadfruit flour reported CHO contents between 73.14% and

89.80% (Edima-Nyah et al., 2019). Iron levels varied between 10.0 mg (FB2) and 10.7 mg (FB3), with FB3 showing a slightly higher concentration. The higher inclusion of jaggery may contribute to the iron content (Nath et al., 2015). Calcium content ranged from 92.3 mg (FB1) to 95.5 mg (FB2). Sodium levels were fairly consistent across formulations (20.1 mg - 24.2 mg). The higher value of calcium and sodium was found in FB2, which incorporated a higher ratio of dried banana and mango. Similar results were found in the Abuengmoh et al., (2022) study. The ratio of the banana and mango flour was increased in the composite bread, and the calcium and sodium content increased. Potassium content was highest in FB3 (36.4 mg) due to the presence of dried banana and other ingredients, which are known for their high potassium content. In the present investigation, the formulated fruit bars had good proximate and mineral content in the FB2 and FB3 variants. Alfheeaid et al., (2023) found less or more findings of mineral content in the fruit-based bar. The iron was 2.51±0.01, calcium was 5.02±0.03, sodium was 1381.50±1.71, and potassium was 492.68±0.88 in mg/kg. Another similar or contradictory finding by AlJaloudi et al., (2024). They formulated high-energy protein bars by using selected dried fruits like apricots, dates, raisins, cranberries, and other compositions. The moisture 24.88±0.93 to 30.38±0.37%, ash 1.77±0.26 to 2.28±0.05%, protein 18.70±1.64 to 22.40±1.59%, fat 17.34±0.13 to 18.97±0.72%, fiber 10.42±0.27 to 10.48±0.32%, iron 3.52 to 3.72 mg/100 g, calcium 126.73 to 140.32 mg/100 g, sodium 7.81 to 8.15 mg/100 g, and potassium 575.80 to 587.39 mg/100 g.

3.2 Phytochemical and Antioxidant Activity

The formulated fruit bar' TPC, TF, tannin, DPPH, and vitamin C were determined, and the results are presented in Fig. 2. The TPC (238.4 mg GAE/100 g) and TF (252.1 mg QE/100 g) showed a significant difference ($P<0.05$) and highest in the variant of FB1. The other, like tannin (60.3 mg/100 g), DPPH (81.2 %), and vitamin C (25.4 mg/100 g), also showed a significant difference ($P<0.05$) but were highest in the variant of FB3. Vitamin C is a potent

antioxidant that enhances immune function and collagen synthesis. The lower levels of phytochemicals and antioxidant activity may be due to ingredient selection and processing effects. The results are closely related to the findings of a relevant study in which 30.69 – 53.92% inhibition of DPPH and 224.33 – 307.33 mg GAE/100 g TPC of date bars (Parn et al., 2015). A similar finding of tannin content in the banana-cashew apple fruit bar in the range of 63.21 – 84.23 mg/100g (Arinzechukwu and Nkama, 2019). The TF content was 370.26 mg CE/100 g found in freshly prepared roselle–fig fruit bar (Aslam et al., 2023). The contradictory result by Kourany et al., (2017). In which they prepared a mango fruit bar, the vitamin C was 105.07 mg/100 g. This was due to adding pectin to the bar.

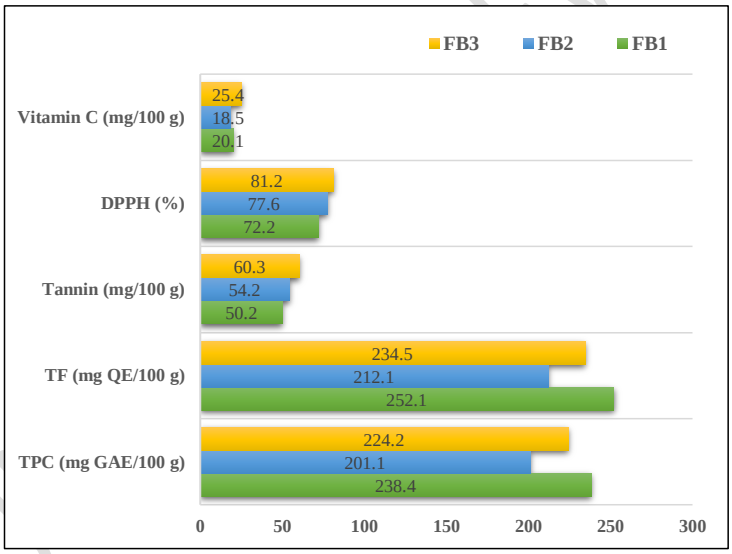

Fig. 2: Phytochemical and Antioxidant Activity of Formulated Fruit Bar

3.3 Physical Properties

Water activity (a_w) is a key parameter in determining the microbial stability, shelf life, and quality of food products. It measures the amount of free water available for microbial growth, with higher values increasing the risk of spoilage due to bacterial and fungal contamination

(Troller and Christian, 2012). The results showed that FB3 had the highest a_w (0.55), correlating with its higher moisture content (6.8%). Since moisture is directly proportional to a_w, this suggests that FB3 may have a slightly higher susceptibility to microbial activity compared to the other formulations. However, even at 0.55, the value remains well below the critical threshold of 0.7, which is the point where microbial spoilage becomes a significant concern (Beuchat, 1981). Conversely, FB2 exhibited the lowest a_w (0.48), indicating better microbial stability due to lower moisture content (5.2%). The FB1 formulation had an intermediate a_w value of 0.50, which is still within a safe range for extended storage. Water activity values below 0.7 inhibit the growth of most pathogenic bacteria and molds, significantly extending the shelf life of the product (Beuchat, 1981). Since all formulated bars maintain $a_w < 0.7$, they can be considered microbiologically stable with a low risk of spoilage (Alp and Bulantekin, 2021). The a_w values of FB1 (0.50), FB2 (0.48), and FB3 (0.55) fall within this optimal range, suggesting that the formulated bars are suitable for long-term storage without refrigeration. Findings of our results are supported by research in mango fruit bar. The a_w lies in the range of 0.57 – 0.69 (Vu et al., 2023).

Texture is a crucial determinant of food quality, influencing consumer preference, sensory perception, and product acceptability. It is assessed through mechanical properties such as hardness and fractureability, which reflect the rheological and structural characteristics of the food product. The hardness of the formulated fruit bars ranged from 418.23 g (FB3) to 432.12 g (FB2), with FB3 exhibiting the lowest hardness and FB2 the highest. Since hardness represents the force required to break the sample, its variation is directly influenced by moisture content. Fractureability represents the extent of deformation before breaking, with higher values indicating a more brittle texture. The highest fractureability was observed in FB3 (41.15 mm), while FB2 (35.25 mm) exhibited the lowest. In FB1 variant (32.12 mm). The formulated fruit bar's low moisture content may be the cause of the hardness increase and decrease in

fractureability. Munir et al., (2016) examined the instrumental texture of fruit bars and found a similar tendency. 405.63 g was the lowest and hardest recorded, while 928.92 g was the highest. The highest fractureability was 37.48 mm, and the lowest was 31.05 in the fruit bar.

3.4 Sensory Evaluation

The sensory evaluation of the prepared fruit bar was assessed by different attributes such as appearance, color, texture, odor, taste, mouthfeel, and overall acceptability as depicted in Fig. 3. For each attribute, a score of 9 was given if the panelist numbered: 9- "like extremely", 8- "like very much", 7- "like moderately", 6- "like slightly", 5- "neither like nor dislike", 4- "dislike slightly", 3- "dislike moderately", 2- "dislike very much", and 1- "dislike extremely". The findings showed a significant difference ($P<0.05$) in the sensory attributes of the different variants of the fruit bar. In all the variants, FB3 was gained more acceptable in all the attributes other than the variants. However, variant FB1 showed a greater reduction in sensory attributes. In Asaduzzaman et al., (2020) study, they prepared mixed fruit bar from mango, pineapple, and papaya in four different variations. S3 variation (50% mango, 14% pineapple, and 20% papaya) received higher acceptability in all the sensory attributes. The hedonic score of different attributes was 7.7 for color, 8.1 for flavor, 8.2 for texture, 8.4 for taste, and 8.1 for overall acceptability. Narayana et al., (2007) prepared a banana fruit bar. The overall acceptability of this bar was 4.50 - 6.79.

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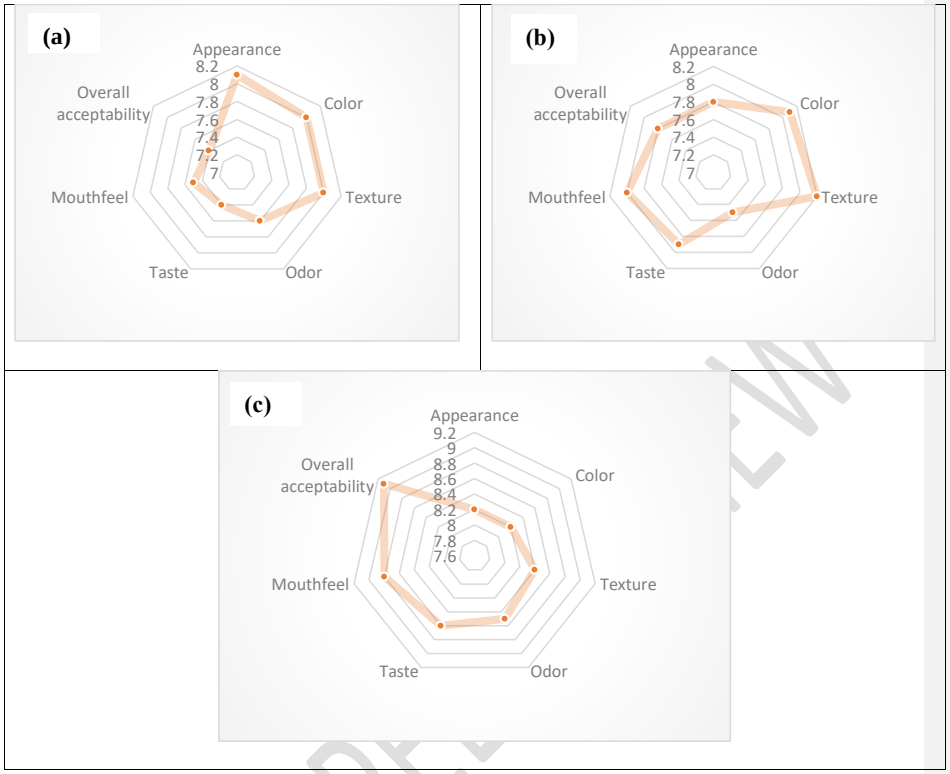

Fig. 3: Sensory Evaluation of Formulated Fruit Bar (a) FB1 variant; (b) FB2 variant; and (c) FB3 variant

3.5 Cost Estimation

In evaluating the cost estimation of the formulated fruit bar variants (FB1, FB2, and FB3), we observe that the ingredient costs per 100 g are approximately Rs. 59.40, Rs. 54.15, and Rs. 56.80, respectively. These estimates are based on current market prices for each component. These costs did not include transport, rent, local taxes, sale commission, packaging, and many others. The cost of the developed formulated fruit bar was lower as compared to the market available yoga bars. A study by Singh et al., (2022) developed a functional snack bar incorporating amaranth grains, oats, and banana peel powder, achieving a cost of Rs. 9.57 per 100 g. The lower cost in this study was primarily due to the use of banana peel powder, an

underutilized and cost-effective ingredient. In contrast, our formulations utilized premium dried fruits and seeds, leading to higher ingredient costs.

4. CONCLUSION

A fruit bar is a convenient, tasty, and often healthy snack option made from a variety of dried fruits, nuts, seeds, and sometimes sweeteners. It's ideal for a quick energy boost, providing natural sugars and essential nutrients. However, the nutritional value can vary depending on the ingredients, so it's important to check for added sugars or artificial additives when choosing a fruit bar. From this study, it has shown that incorporating all selected fruits in dried form improved the nutritional (FB2 and FB3) and sensory evaluation of the FB3 variant of the fruit bar. All the selected fruits are rich in nutritional profile as well as phytochemical and antioxidant activity. The cost of the formulated fruit bar was in low price as compared to the market yoga bar. This fruit bar not only enhances market revenue but also supports immunity, making it beneficial for individuals of all ages, particularly children. Further research is required to assess its shelf stability and identify the most suitable packaging material that can enhance its longevity and quality.

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DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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