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Production of Nutritious and Healthy Functional Vegetarian Bars for Fitness Athletes

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ABSTRACT

With the development of the food trade, tremendous changes in the eating patterns of athletes have been observed. Bars represent convenient, ready-to-eat and properly portioned food items that not only provide the body with nutrients but also provide a feeling of satiety. This study aimed to formulate new high-protein and energy plant-based functional bars for athletes. Eight bars were formulated from plant sources and spirulina with different salty and sweet flavors. The bars were evaluated for chemical composition and content of minerals, phenolic and flavonoids. Protein digestibility *in vitro* and antioxidant activity were estimated, and sensory properties were evaluated, as well as caloric values and recommended dietary allowances (RDA). The results confirmed that the protein content of the bars ranged from 13.3 to 25.79%, energy from 456.28 to 528.64 kcal/100 g, potassium and iron from 3373.82 to 4901.91 ppm and 106.95 to 603.77 ppm, respectively. The protein digestibility values ranged from 45.86 to 76.45%. The sensory evaluation results showed that all bar formulas were acceptable with values ranging from 6.5 to 9 for general acceptability. The shelf life of the bars was 7 weeks at room temperature (25-30°C), while it reached 11 weeks at 4°C. In conclusion, manufactured bar formulas with high acceptability and antioxidant activity can provide athletes and consumers in general with a high percentage of their nutrient requirements.

1. Introduction

One of the most important goals of sports science and nutrition is athletic success. Therefore, it is necessary to understand the science of athletes' nutrition to maintain the health of athletes, avoid fatigue, and motivate them to perform appropriate training. It is also important for them to eat healthy snacks rich in nutritional content, thus ensuring that their diet supplies them with nutrients regularly. Food fortification is among the techniques commonly used to develop or formulate functional foods (Vyas and Saini, 2018). Before and during strenuous competitions, athletes must pay close attention to their diet, as proper nutrition is linked to good physical performance (Baranauskas et al., 2015). The timing and nutrient composition of meals, including breakfast, main meals, and snacks, are essential for athletes. To sustain energy levels and promote continuous muscle development, athletes should consume several meals at least five per day (Smith et al., 2015).

Nutritional supplements are crucial for young athletes, regardless of gender, to optimize performance. Research shows that the most popular supplements among athletes are creatine, sports drinks, sports bars, whey protein, and caffeine, indicating a connection between supplement consumption and physical performance influenced by gender and playing positions (Sebastiá-Rico et al., 2024). Complete meals at affordable prices are essential for athletes to achieve good nutrition, and energy bars are a convenient and nutritious option that can provide athletes with nutrients and quick energy.

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Several studies have shown the potential of energy bars to promote health and enhance physical performance by incorporating key ingredients such as quinoa leaves in bread (Świeca et al., 2014), spirulina (Doiphode and Mane, 2021), whey protein isolate and soy protein isolate (Jovanov et al., 2021), chocolate-covered spirulina and almond bars (Barmare and Battalwar, 2023), or seeds of the Cucurbitaceae family (watermelon and pumpkin) (Chaudhary et al., 2024). A study of 24 commercial bars sold as energy bars was conducted, as they are high in energy and are mainly based on high carbohydrate and fat content. The carbohydrate content was found to be between 20 and 50 g, but it was low in protein content, as it was found to be less than 10 g of protein per bar weighing 40 to 60g. Most of these bars were found to have an unacceptable taste, and a few had an acceptable taste (Rajabi, 2017). Nutritious, ready-to-eat, nutrient-rich snacks are crucial for fitness athletes to ensure they get their nutrients quickly and easily (Vyas and Saini, 2018). Spirulina is recognized for its exceptional nutritional value, boasting high levels of proteins, vitamins, minerals, and beneficial fatty acids like omega-3 and omega-6. It contained amounts of total fat and cholesterol lower than other foods. Furthermore, the high level of bioactive substances found in it, such as phenols, phycocyanin pigment, and polysaccharides, play a role in different biological functions such as serving as antioxidants and possessing anti-inflammatory properties. Spirulina is widely utilized in the development of medicinal foods, functional foods, and dietary supplements (AlFadhly et al., 2022). The autoimmune condition known as celiac disease, which mostly affects the small intestine and is brought on by gluten consumption in genetically predisposed people, has been affecting athletes more and more recently. A sophisticated immune reaction to gluten proteins is necessary for the onset of celiac disease (Tamai and Ihara, 2023). The gluten-free diet (GFD) has grown in popularity beyond its primary medical applications, such as the treatment of celiac disease (CD), gluten ataxia, wheat allergy, and non-celiac gluten sensitivity. However, the diet has certain disadvantages, such as high prices, nutritional deficits, and social and psychological restrictions (Aljada et al., 2021). Today, a lot of people who are always on the road choose nutrition bars over other foods. The bars give a quick and convenient meal option that doesn't require preparation and has a long shelf life. Because they believe they are healthier options than other foods, many consumers take them as quick snacks or meal replacements (Sonam and Mishra, 2016). The current study aimed to produce eight distinct high-protein and energy bars that are made from plant sources and spirulina, and have a high nutritional value to suit a wide spectrum of people, including vegetarians and fitness athletes.

2. Materials and Methods

Materials

The ingredients were carefully selected to be gluten-free and lactose-free. Lentil seeds (*Lens culinaris*), yellow lentils, pumpkin, yellow corn flour, peanut, pumpkin seeds, salt, chia seeds, flaxseeds, sesame seeds, chili, lemon salt, ground cumin, date molasses, coconut, dark chocolate, and molasses were purchased from local market, Cairo, Egypt. Spirulina powder was obtained from Algal Biotechnology Unit, National Research Centre, Dokki, Giza, Egypt. All chemicals used were of analytical reagent grade and were obtained from Sigma-Aldrich (St. Louis, MO, USA).

Methods

Preparation of sprouted lentils

Sprouted lentils were prepared using the method outlined by Fouad and Rehab (2015). Lentil seeds (*Lens culinaris*) were thoroughly washed with tap water to remove impurities and then soaked in potable water (1:10 w/v) at room temperature for 16 hours. The soaked seeds were placed between thick layers of cotton cloth, and allowed to germinate darkness until the root length reached 2-3cm.

Throughout this process, the seeds were consistently sprayed twice daily with drinking water. Following germination, the sprouted lentils were stored in glass jars at 4°C for further analysis.

Preparation of peanut butter

According to Sithole et al. (2022), the peanut butter was prepared with some modifications by peeling 500 grams of peanuts to remove the red shell. Then, the peanut peels were exposed to a fan to remove any remaining skin. Next, the peeled peanuts were ground in an electric grinder (Braun, model 1021, Germany) until a completely smooth and homogeneous paste was formed. The peanut butter was stored in a clean, dry jar at 4°C for further use and analysis.

Preparation of peeled pumpkin seeds

Pumpkin seeds were peeled by manually removing the outer covering from 500 grams of seeds, following the method of Manda Devi et al. (2018) with minor modifications. The seeds were then placed before a fan to remove any remaining peels. The peeled pumpkin seeds were crushed into small pieces using a mortar and pestle. Finally, the pieces were stored in dry, clean, and dark glass containers at 4°C until they were needed for further use and analysis.

Preparation of chili and lemon

Chili and lemon were meticulously prepared as a flavoring agent according to Pawar et al. (2011) with some modifications. Red peppers were dried at 50°C for 48 hours and then finely ground in an electric grinder (Braun, model 1021, Germany). The ground red pepper was mixed with lemon salt in a 1:1 ratio. The resulting mixture was stored in dry, clean bottles at room temperature for future use and analysis.

Formulation and preparation of vegetarian bar mixtures for fitness athletes

Eight unique snack mixtures were meticulously prepared for the fitness athlete, as detailed in Table 1.

Table 1. Formulation of vegetarian bar mixtures for fitness athletes

Ingredients (g)	Formula							
	F1	F2	F3	F4	F5	F6	F7	F8
	Salty bars						Sweet bars	
Sprouted lentils	100	100	100	-	-	-	-	-
Yellow lentils	-	-	-	-	-	-	100	-
Spirulina powder	-	-	-	35	35	35	-	35
Pumpkin	100	100	100	100	100	100	100	100
Water	109	103	103	174	168	168	55	120
Yellow corn flour	30	30	30	30	30	30	30	30
Peanut butter	60	60	60	60	60	60	60	60
Peeled pumpkin seeds	25	25	25	25	25	25	25	25
Salt	5	5	5	5	5	5	-	-
Chia seeds	71	50	50	71	50	50	50	50
Flaxseeds	-	21	-	-	21	-	-	-
Sesame seeds	-	-	21	-	-	21	-	-
Chili and lemon	-	6	-	-	6	-	-	-
Ground cumin	-	-	6	-	-	6	-	-
Date molasses	-	-	-	-	-	-	25	25
Coconut	-	-	-	-	-	-	14	14
Dark chocolate	-	-	-	-	-	-	16	16
Molasses	-	-	-	-	-	-	25	25

Six of the mixtures have a salty flavor profile. Three of these mixtures are enhanced with sprouted lentils and blended with chia seeds, flaxseeds, or sesame seeds (F1, F2, and F3, respectively). The other three are enriched with spirulina powder and combined with chia seeds, flaxseeds, or sesame seeds (F4, F5, and F6, respectively). Additionally, there are two sweet-flavored mixtures, one featuring yellow lentils (F7) and the other containing spirulina powder (F8).

Preparation of vegetarian bar mixtures for fitness athletes

Preparation of salty bars for fitness athletes

One hundred grams of pumpkin was cooked with 100 grams of sprouted lentil (F1, F2, and F3) or with 35 grams of spirulina powder (F4, F5, and F6) in a pressure cooker for 10 minutes, using an appropriate amount of water as indicated in Table 1. The cooked mixtures were thoroughly blended in a hand blender (Braun hand blender, Germany) with 30 grams of yellow corn flour, 60 grams of peanut butter, 25 grams of peeled pumpkin seeds, 5 grams of salt and 50 grams of chia seeds until smooth and homogeneous, then formed into bars. Twenty-one grams of chia seeds were sprinkled on F1 and F4, while F2 and F5 were topped with 21 grams of flaxseeds and 6 grams of chili and lemon spices.

F3 and F6 were adorned with 21 grams of sesame seeds and 6 grams of ground cumin spice. The bars were baked in a Thermo Scientific Precision Compact oven (Fisher Scientific, USA) at 180°C for 10 minutes, then cut into bars measuring 10 cm x 2.5 cm x 1 cm (length x width x thickness, respectively) and bake for another 10 minutes at 180°C. The salty bars were left to cool at room temperature and packaged in high-density polyethylene bags. The salty bars were stored in two places: one at 4 °C and the other at room temperature (25-30°C) in a well-ventilated location (Figures 1 and 2).

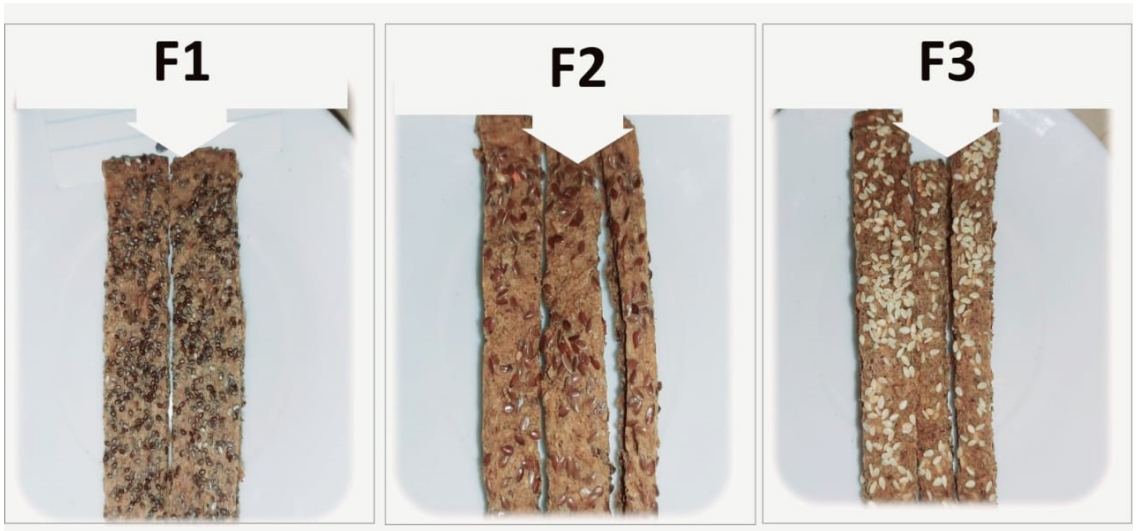

Figure 1.

F1: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F2: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F3: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.

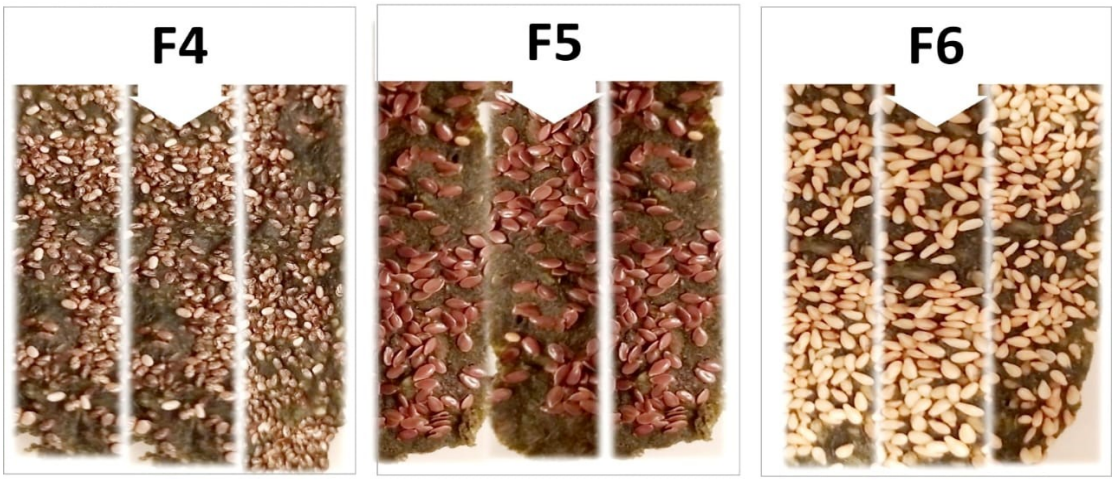

Figure 2.

F4: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F5: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F6: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.

Preparation of sweet bars for fitness athletes

One hundred grams of pumpkin was cooked with 100 grams of yellow lentil flour (F7) or with 35 grams of spirulina powder (F8) in a pressure cooker for 10 minutes in the presence of a suitable amount of water as shown in Table 1. Then, the cooked mixtures were well mixed in a hand blender (Braun hand blender, Germany) with 30 grams of yellow corn flour, 60 grams of peanut butter, 25 grams of peeled pumpkin seeds, 50 grams of chia seeds, 25 grams of date molasses and 25 grams of molasses until become smooth and homogeneous, then formed into bars. Fourteen grams of coconut and sixteen grams of dark chocolate were sprinkled for F7 and F8 on the surface of the bars. The bars were baked in a Thermo Scientific Precision Compact oven (Fisher Scientific, USA) at 180 °C for 10 minutes, then they were cut into bars with the following dimensions of 10 cm*2.5 cm*1 cm (length * width * thickness, respectively) and continued baking at 180°C for another 10 minutes. Then the sweet bars were left to cool at room temperature and packaged in high-density polyethylene bags. The sweet bars were stored in two places: one at 4°C and the other at room temperature (25-30°C) in a well-ventilated location (Figure 3).

Figure 3.

F7: Yellow lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.
F8: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.

Analytical methods

Chemical composition

The chemical compositions of the raw material and the eight prepared bar mixtures for the fitness athlete were rigorously analyzed using methods outlined in AOAC (2016). This comprehensive analysis included moisture, ash, fat, and protein contents, with carbohydrate content accurately calculated by difference. Furthermore, mineral contents including magnesium (Mg), iron (Fe), calcium (Ca), potassium (K), and sodium (Na) were precisely measured using an Agilent Technologies atomic absorption spectrophotometer instrument as specified in AOAC (2016).

Caloric value

Total calories of the eight prepared bar mixtures for the fitness athlete were calculated using the equation provided by James (1995) as follows:

Total calories (Kcal/100g) = Protein *4 + Fat *9 + Carbohydrates *4.

In vitro protein digestibility

The protein digestibility of the eight prepared bar samples for the fitness athlete was determined using the method described by Saunders et al. (1973). After the samples were digested with pepsin and pancreatin enzymes, the protein content in the resulting supernatant was measured using the Kjeldahl method. The percentage of protein digestibility was calculated by dividing the protein in the supernatant by the protein in the samples, as shown in the following equation:

$$Protein\ digestibility\ (\%) = \frac{N\ in\ supernatant - N\ in\ Blank}{N\ in\ sample} \times 100$$

N: nitrogen

Phenolic and flavonoid compounds contents of the prepared vegetarian bar samples for the fitness athlete

Total phenolic compound contents of the eight prepared bar samples for the fitness athlete were determined colorimetrically using the Folin–Ciocalteu reagent (as gallic acid equivalent) according to the method described by Singleton et al. (1999). Total flavonoid compounds were determined (as quercetin equivalent) according to the methods of Marinova et al. (2005).

Antioxidant activity of the prepared vegetarian bar samples for the fitness athlete

The antioxidant activity of the prepared bar samples for the fitness athlete and butylated hydroxyanisole (BHA) was assayed using 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical according to Rattanachitthawat et al. (2010).

Sensory analysis

Sensory analysis was conducted at the Department of Food Science, Faculty of Agriculture, Cairo University, and a fitness gym.

The evaluation took place in a well-lit environment at a constant room temperature of 20-25°C. Twenty panelists, aged 25-35 years, including ten staff members from the Department of Food Science and ten individuals from the fitness gym, participated in the evaluation using a 9-point hedonic scale. On this scale, 1 represents dislike extremely, 2 represents dislike very much, 3 represents dislike moderately, 4 represents dislike slightly, 5 represents neither like nor dislike, 6 represents like slightly, 7 represents 'like moderately, 8 represents like very much, and 9 represents like extremely. A score of 5 or higher is considered acceptable, while a score below 5 is deemed unacceptable. Each panelist was provided with drinking water to rinse their mouth before testing the next sample. Product attributes evaluated included color, appearance, taste, texture, flavor, and overall acceptability (Larmond, 1994).

Microbiological analysis

The microbiological analysis of the salty and sweet bars samples was evaluated for shelf-life at different temperatures (4°C and at room temperature in a well-ventilated location for 12 weeks) following organoleptic evaluation. Samples were taken every 14 days during storage and analyzed. Each sample weighing 10 g was placed in a sterile saline solution of 90 mL to create the dilutions.

Total Plate count and Yeast and mold counts

Microbiological analyses during storage were conducted using total plate count agar (PCA) incubated at 30°C for 48-72 hours to enumerate total viable counts (TVCs). Yeast and mold counts were determined using acidified malt agar medium, and the plates were incubated at 20-25°C for 5 days. Colonies were counted after 3 and 5 days (Aneja, 2003).

Coliform bacteria

Coliform bacteria were determined according to the APHA (1976) method.

Proteolytic bacteria

Proteolytic bacteria were counted using nutritional agar medium and 10% sterile skimmed milk following the procedure outlined by Brock et al. (1982) and Difco Manual (1984). The plates were incubated for three days at 30°C. After incubation, the plates were flooded with 1% HCl, and the clear zone colonies were measured.

Lipolytic bacteria

The Difco Manual (1984) and Harrigan and McCance (1976) procedures were used to count the lipolytic bacteria in 10% olive oil. After 5 days of incubation at 37°C, the plates were flooded with saturated copper sulfate solution, and the colonies' color changes were counted.

Detection of *Staphylococcus aureus*

Staphylococcus aureus was detected using Baird-Parker medium plus 5 ml egg yolk tellurite emulsion added to each 100 ml of sterilized media, which was mixed well before pouring into the plates. The plates were incubated at 37°C for 24 hours as described by APHA (1976) and Difco Manual (1984).

Detection of *Salmonella sp.*

The detection of *Salmonella sp*. was conducted according to Nyangena et al. (2020).

Statistical analysis

Statistical analyses were carried out by the SPSS 19 program. Data were expressed as means. The Statistical analysis was performed using a one-way analysis of variance followed by Duncan's tests as outlined by Snedecor and Cochran (1980).

3. Results and Discussion

Chemical composition of raw material

The raw materials were analyzed for their moisture, ash, fat, protein, and carbohydrate contents, and the obtained results are shown in Table 2. Moisture content ranged from 95.8% for pumpkins to 1.58% for chocolate. Four ingredients (pumpkin, sprouted lentils, date molasses, and molasses) had a moisture content of at least 25%, while the remaining components had a moisture content of approximately 11% or less. Ash contents varied from 0.42% for pumpkin to 6.75% for spirulina powder. Nearly half of the ingredients had a high-fat percentage, ranging from 16% in ground cumin to 67.83% in coconut. The other half had a fat content of no more than 7%, with pumpkin having the lowest fat content (0.13%) and spirulina powder (6.48%). The highest values of protein content were observed for spirulina powder (64.4%), followed by peeled pumpkin seeds (30.05%), peanut butter (25.63%), yellow lentil (23.3%), then flaxseeds (21.11%), and the lowest value was that of molasses (zero).

Chili and lemon showed the highest percentage of carbohydrates (76.28%), followed by yellow corn flour (76.07%), while pumpkins showed the lowest carbohydrate value (2.63%). The same results also indicated that the caloric value ranged from 726.91 Kcal/100g for coconut to 15.77Kcal/100g for pumpkins. The study also revealed that certain ingredients are high in energy, with more than 400 Kcal/100g. These high-energy ingredients, listed in descending order, include coconut, sesame seeds, peeled pumpkin seeds, dark chocolate, peanut butter, flaxseeds, chia seeds, and ground cumin. The remaining ingredients had similar calorie levels, ranging between 300-400 Kcal/100g, while sprouted lentils contained less than 160 Kcal/100g. These results are consistent with Rahman, et al. (2019) for pumpkin seeds, Riyad et al. (2020) for spirulina, Shibli et al. (2019) for peanuts butter, Dhull et al. (2022) for lentils, Kulczyński et al. (2019) for chia, Hussain et al. (2008) for flaxseeds, Idowu et al. (2021) for sesame seeds, Mahdi et al. (2022) for date molasses and Samanta et al. (2022) for dark chocolate.

According to Sadeghi et al. (2022), Spirulina is recognized for its valuable nutritional profile, being a great source of protein (55-70%), carbohydrates (30%), and fats (8%).

Table 2. Chemical composition of raw material on fresh weight basis

Ingredients	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate* (%)	Caloric value (Kcal/100g)
Sprouted lentils	59.60^{b} ± 0.69	1.41^{fg} ± 0.12	0. 61^{l} ± 0.02	8.91^{i} ± 0.07	29.47^{j} ± 0.27	159.01^{l} ± 1.13
Yellow lentils	8.87^{f} ± 0.08	2.27^{cd} ± 0.13	2.04^{k} ± 0.30	23.3^{d} ± 0.13	63.52^{d} ± 0.36	365.64^{j} ± 1.20
Spirulina powder	6.31^{g} ± 0.27	6.75^{a} ± 0.07	6.48^{i} ± 0.34	64.4^{a} ± 0.56	16.06^{m} ± 0.07	380.16^{i} ± 1.21
Pumpkin	95.80^{a} ± 0.64	0.42^{h} ± 0.17	0.13^{l} ± 0.02	1.02^{m} ± 0.04	2.63^{o} ± 0.03	15.77^{m} ± 0.01
Yellow corn flour	8.54^{f} ± 0.24	1.13^{g} ± 0.09	4.94^{j} ± 0.21	9.32^{i} ± 0.11	76.07^{a} ± 0.28	386.02^{i} ± 1.24
Peanut butter	2.22^{jk} ± 0.12	2.50^{cd} ± 0.17	35.59^{e} ± 0.06	25.63^{c} ± 0.18	34.06^{i} ± 0.21	559.07^{e} ± 1.63
Peeled pumpkin seeds	2.46^{jk} ± 0.19	6.61^{a} ± 0.06	46.83^{c} ± 0.59	30.05^{b} ± 0.21	14.05^{n} ± 0.06	597.87^{c} ± 1.58
Chia seeds	4.69^{h} ± 0.17	4.78^{b} ± 0.12	31.02^{g} ± 0.38	15.52^{g} ± 0.08	43.99^{g} ± 0.34	517.22^{g} ± 1.14
Flaxseeds	5.73^{h}± 0.13	1.78^{de} ± 0.09	32.49^{f} ± 0.64	21.11^{e} ± 0.22	38.89^{h} ± 0.31	532.41^{f} ± 1.31
Sesame seeds	2.53^{j} ± 0.07	2.58^{c} ± 0.24	52.86^{b} ± 0.59	17.62^{f} ± 0.17	24.41^{l} ± 0.18	643.86^{b} ± 1.68
Chili and lemon	3.53^{i} ± 0.19	6.34^{a} ± 0.21	1.76^{k} ± 0.13	12.09^{h} ± 0.05	76.28^{a} ± 0.67	369.32^{j} ± 1.18
Ground cumin	11.03^{e} ± 0.09	2.37^{cd} ± 0.13	16.02^{h} ± 0.08	17.75^{f} ± 0.13	52.83^{e} ± 0.43	426.50^{h} ± 1.14
Date molasses	26.07^{c} ± 0.17	1.32^{g} ± 0.06	5.07^{j} ± 0.24	2.70^{l} ± 0.08	64.84^{c} ± 0.31	315.79^{k} ± 1.16
Coconut	1.59^{k} ± 0.12	1.47^{fg} ± 0.19	67.83^{a} ± 0.65	3.25^{k} ± 0.04	25.86^{k} ± 0.22	726.91^{a} ± 1.39
Dark chocolate	1.58^{k} ± 0.12	2.12^{de} ± 0.06	38.08^{d} ± 0.28	7.71^{j} ± 0.03	50.51^{f} ± 0.48	575.60^{d} ± 1.42
Molasses	25.01^{d} ± 0.24	1.39^{fg} ± 0.16	2.62^{k} ± 0.12	zero	70.98^{b} ± 0.59	307.50^{k} ± 1.09

Values are mean of three replicates ± SD, number in the same column followed by the same letter is not significantly different at 0.05 level; *Carbohydrates: was calculated by difference

Chemical composition of vegetarian bars for fitness athletes

The proximate composition of resultant bars is tabulated in Table **3**. The results presented in Table 3 indicated that moisture contents of all bars ranged between 8.97% (F7) and 5.73% (F8). The ash values of the bar samples were found to be low, with the highest value (8.91%) in sample F5 and the lowest value (2.84%) in sample F7. The bar samples contained a high fat content, ranging from 32.64% in F8 to 23.61% in F1. Moreover, sweet bars exhibited a higher fat content than salty bars, likely due to the inclusion of coconut (67.83% fat) and dark chocolate (38.08% fat) in the sweet bar formulations. In terms of protein content, sweet bars had lower levels compared to salty bars. This may be attributed to the ingredients in the sweet bar formulas, which include eleven ingredients, four of which (date molasses, coconut, dark chocolate, and molasses) are not found in salty bars and have lower protein percentages. The protein values for the salty bars were relatively similar, with the highest value at 25.79% for F1 and the lowest at 22.53% for F5. Sweet bars did not exceed 15.18% in protein content. The findings showed that sweet bars have a higher percentage of carbohydrates than salty bars, which may also be due to the ingredients in the sweet bar formulas. Carbohydrate levels ranged from 45.42% in F8 to 34.28% in F3. Based on these findings, the caloric value ranged between 528.64 Kcal/100g for F8 and 456.28 Kcal/100g for F2. Additionally, all salty bars had lower calories compared to sweet bars. According to Volpe (2007), athletes training for more than 1.5 hours daily require an energy intake of 50 kcal/kg of body weight. Athletes on low-energy diets should prioritize adequate intake of iron, calcium, and magnesium, as these minerals are crucial for exercise-related reactions. Jovanov et al. (2021) reported that bars prepared from whey protein isolate and soy protein isolate contained 34% protein, 288 kcal of energy, 6 g of fat (including 3 g of saturated fat), 23 g of carbohydrates (including 1.5 g of sugars), and 21.5 g of starch.

Table 3. Chemical composition of vegetarian bars for fitness athletes on fresh weight basis

Bars		Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate* (%)	Caloric value (Kcal/100g)
F1	Salty bars	7.51^{b}±0.33	5.89^{d}±0.30	23.61^{e}± 0.17	25.79^{a}±0.69	37.20^{c}±0.06	464.45^{e}±0.70
F2		8.49^{a} ±0.13	7.49^{b} ±0.23	24.04^{e}±0.32	24.08^{bc}±0.06	35.90^{d}±0.26	456.28^{f}±1.22
F3		6.60^{cd} ±0.22	5.65^{d} ±0.13	28.35^{c}±0.02	25.12^{ab}±0.24	34.28^{f}±0.05	492.75^{c}±1.03
F4		6.14^{de}±0.08	7.32^{bc}±0.12	25.98^{d} ±0.17	24.58^{ab}±0.71	35.98^{d}±0.06	476.06^{d}±1.74
F5		7.11^{bc}±0.14	8.91^{a} ±0.02	26.35^{d} ±0.24	22.53^{d}±0.25	35.10^{e}±0.44	467.67^{e}±1.35
F6		5.94^{de}±0.08	6.83^{c}±0.12	29.07^{c} ±0.64	23.12^{cd}±0.06	35.04^{e}±0.36	494.27^{c}±1.28
F7	Sweet bars	8.97^{a} ±0.48	2.84^{e}±0.19	30.23^{b}±0.08	15.18^{e}±0.33	42.78^{b}±0.11	503.91^{b}±1.74
F8		5.73^{e}±0.30	2.91^{e}±0.30	32.64^{a} ±0.33	13.30^{f}±0.24	45.42^{a}±0.26	528.64^{a}±0.65

Values are mean of three replicates ± SD, number in the same column followed by the same letter is not significantly different at 0.05 level; *Carbohydrates: was calculated by difference
F1: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F2: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F3: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F4: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F5: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F6: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F7: Yellow lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.
F8: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.

According to Veggi et al. (2018), as the chia seeds percentages increased in protein bars from zero to 20%, the chemical composition of the four bars indicated the following ranges: 19.53 - 20.39% moisture, 2.3-2.4% ash, 20.28-23.42% protein, 19.09 - 19.72% fat, 34.73-38.01% carbohydrates, and 319.70-355.53 kcal/100g energy. Barmare and Battalwar (2023) found that chocolate-coated spirulina and almond bars were high in protein and met the protein needs of fitness athletes.

Minerals content of vegetarian bars for fitness athletes

Minerals are essential for maintaining the body's vital functions and overall health, and they play a crucial role in preventing various diseases, including cardiovascular diseases, anemia, high blood pressure, Alzheimer's disease, and goiter (Hoffman, 2017). Table 4 presents the mineral contents of the salty and sweet bars. All bars in this study showed high levels of potassium and sodium. F3 contained the highest levels of magnesium and potassium (2.45 and 4901.91 ppm, respectively), while F2 had the highest levels of iron and sodium (603.77 and 42452.82 ppm, respectively). F5 showed the highest level of calcium (4.14 ppm) compared to the other bars. Conversely, F7 was found to have the lowest levels of all minerals (1.01 ppm magnesium, 106.95 ppm iron, 3373.8 ppm potassium, and 3361.67 ppm sodium) except for calcium. F4 contained the lowest level of calcium (1.64 ppm) compared to the other bars. Furthermore, it was observed that there were no significant differences ($P \leq 0.05$) between all bars for potassium, and also, it was observed that there were no significant differences ($P \leq 0.05$) between F5 and F6 for magnesium, as well as between F3 and F8 for iron, and also between F6, F2, and F1 for calcium. However, there were no significant differences ($P \leq 0.05$) between F5, F4, and F6, for sodium. Also, in general, it was found that most of the levels of mineral values in salty bars were higher than the values of sweet bars, except F7 for calcium and F8 for

magnesium and iron, and this may be attributed to the ingredients of the bars. According to Branger et al. (2003), Shimamatsu (2004) and Sadeghi et al. (2022), spirulina is a rich source of minerals, including essential minerals such as calcium, magnesium, potassium, phosphorus, iron, and zinc. Therefore, bars containing spirulina were found to have significant amounts of most minerals. The insufficient consumption of minerals in the diet can often lead to a higher vulnerability to infectious diseases because it weakens the immune system (Jayasinghe et al., 2016). Athletes, especially those engaged in endurance activities or with dietary restrictions, require essential nutrients such as iron, calcium, sodium, and potassium to support nerve impulse transmission and prevent muscle cramps, weakness, and fatigue, which is crucial for peak performance (Carlsohn et al., 2020).

Table 4. Minerals content of vegetarian bars for fitness athletes (ppm) on dry weight basis

Bars		Mg	Fe	Ca	K	Na
F1	Salty bars	$2.19^{b} \pm 0.031$	$135.53^{f} \pm 0.07$	$2.19^{d} \pm 0.01$	$4385.96^{a} \pm 0.13$	$23684.18^{d} \pm 0.56$
F2		$1.89^{c} \pm 0.001$	$603.77^{a} \pm 0.70$	$2.36^{d} \pm 0.08$	$4716.98^{a} \pm 0.62$	$42452.82^{a} \pm 1.21$
F3		$2.45^{a} \pm 0.002$	$266.66^{c} \pm 1.52$	$2.94^{c} \pm 0.02$	$4901.91^{a} \pm 0.01$	$34803.55^{b} \pm 2.54$
F4		$1.64^{d} \pm 0.003$	$149.59^{e} \pm 1.33$	$1.64^{f} \pm 0.01$	$4098.36^{a} \pm 0.13$	$28688.52^{c} \pm 1.15$
F5		$1.38^{f} \pm 0.002$	$386.36^{b} \pm 0.65$	$4.14^{a} \pm 0.01$	$4604.51^{a} \pm 1.33$	$29468.86^{c} \pm 1.13$
F6		$1.35^{f} \pm 0.002$	$193.58^{d} \pm 0.64$	$2.37^{d} \pm 0.02$	$3378.38^{a} \pm 1.85$	$27027.04^{c} \pm 0.33$
F7	Sweet bars	$1.01^{g} \pm 0.002$	$106.95^{g} \pm 0.49$	$3.37^{b} \pm 0.02$	$3373.82^{a} \pm 0.65$	$2361.67^{f} \pm 1.91$
F8		$1.56^{e} \pm 0.013$	$265.63^{c} \pm 0.76$	$1.92^{e} \pm 0.01$	$3906.25^{a} \pm 0.55$	$3906.25^{e} \pm 0.64$

Values are mean of three replicates ± SD, number in the same column followed by the same letter is not significantly different at 0.05 level.
F1: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F2: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F3: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F4: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F5: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F6: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F7: Yellow lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.
F8: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.

In vitro protein digestibility of vegetarian bars for fitness athletes

Protein digestibility and absorption are directly correlated with food quality. As a result, protein digestibility is critical because it supports physiological processes like tissue growth, repair, and enzyme synthesis. This is especially true for young children, athletes, and people who are protein deficient. Accurately estimating digested protein is of great significance for public health (Schaafsma, 2000 and FAO/WHO/UNU., 2007). Protein is essential for the formation and repair of bodily cells. Protein deficiency can cause a variety of health consequences, including kwashiorkor, marasmus, decreased mental health, oedema, organ failure, muscle tissue wasting and shrinking, and immune system weakening (Khan et al., 2017). The protein digestibility of bars for fitness athletes is presented in Table 5. The results indicated that the protein digestibility of F6 and F4 was approximately the same, ranging between 69.70% and 71.34%, respectively and were not significantly different ($P \leq 0.05$). The same trend was observed for F3 and F5. However, F5, F3, F1, and F2 showed the lowest protein digestibility (56.42%, 55.40%, 48.83%, and 45.86%, respectively). Also, the results indicated that sweet bars had a higher digestible protein value than salty bars, except for F4 and F6. These results may be due to

these bars including spirulina, which has a high protein content and digestibility. Legumes lose some nutritional value when antinutritional factors are present because they hinder digestion and make protein less soluble (Gilani et al., 2012 and Avilés-Gaxiola et al., 2018). Barbana and Boye (2013) found that the *in vitro* protein digestibility of flours and protein concentrates from two types of lentils (*Lens culinaris*) ranged from 75.90% to 77.05% for the flours, while the concentrates exhibited significantly higher values of approximately 82.80% to 83.20%. On the other hand, Devi et al. (2018) indicated that the average digestibility of essential amino acids in spirulina protein was 85.2%.

Table 5. Protein digestibility of vegetarian bars for fitness athletes

Bars		Protein digestibility (%)
F1	Salty bars	$48.83^{e} \pm 0.72$
F2		$45.86^{f} \pm 0.02$
F3		$55.40^{d} \pm 0.75$
F4		$71.34^{b} \pm 0.66$
F5		$56.42^{d} \pm 0.23$
F6		$69.70^{b} \pm 0.60$
F7	Sweet bars	$62.65^{c} \pm 0.62$
F8		$76.45^{a} \pm 0.69$

Values are mean of three replicates ± SD, number in the same column followed by the same letter is not significantly different at 0.05 level.
F1: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F2: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F3: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F4: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F5: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F6: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F7: Yellow lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.
F8: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.

Phenolic and flavonoid compounds contents of vegetarian bars for fitness athletes and its antioxidant activity

The results presented in Table 6 showed the total phenolic and flavonoid contents, as well as the antioxidant activity of bars designed for fitness athletes. The results indicated that F8 and F7 contained the highest amount of phenolic compounds (3976.43 and 2888.32 mg GAE/100g, respectively), while F1 and F2 had the lowest amounts (1179.29 and 911.35 mg GAE/100g, respectively). Significant differences ($P \leq 0.05$) were observed between all bar samples. Sweet bars demonstrated higher levels of phenolic compounds compared to salty bars, likely due to the presence of spirulina in the sweet bars, which are known for their high phenolic compound content. Salty bars containing spirulina also had higher phenolic compound levels than those containing lentils.

In summary, the sweet bars ranked in descending order as F8, then F7, while the salty bars ranked as F4, F6, F5, F1, and F2, with the exception of F3. A similar trend was observed for the flavonoid content in the bars, which ranged between 1783.24 mg Quercetin E/100g in F8 and 249.45 mg Quercetin E/100g in F2. Phenolic compounds play a critical role in preserving the health of the digestive system and protecting against harm caused by reactions in the stomach and intestines (Halliwell, 2007).

According to Sharma (2006), flavonoids offer numerous health benefits for humans by acting as antioxidants and neutralizing free radicals, enhancing blood circulation, particularly in individuals with Alzheimer's disease, as well as exerting anti-cancer,

anti-tumor, and anti-microbial effects. Naturally abundant in several bioactive substances like phytosterols, saponins, and polyphenols, lentils are a highly beneficial food. Because of its bioactive components, eating lentils may help lower the occurrence of many chronic diseases. The most prevalent polyphenols found in lentils are phenolic acids, flavan-3-ols, flavonols, anthocyanidins, proanthocyanidins, and anthocyanins. Because of their potent antioxidant properties, anthocyanins are significant in preventing numerous human degenerative diseases (Mustafa et al., 2022). The antioxidant activity of salty and sweet bars was determined by the DPPH method and the results are shown in Table 6. F8, F7, F6, F4 and F3 exhibited the highest values for antioxidant activity (95.86, 94.12, 92.91, 91.88, and 90.25%, respectively), with significant differences ($P \leq 0.05$) observed between them. In contrast, F5 (86.23%), F1 (85.45%), and F2 (84.23%) recorded the lowest values, with significant differences ($P \leq 0.05$) among them. The study findings indicated that sweet bars generally have higher antioxidant activity compared to salty bars. Moreover, there is a direct correlation between the antioxidant activity of the bars and their phenolic and flavonoid compound content. Stryjecka et al. (2023) found that pumpkin contains an abundance of phenolic compounds, namely protocatechuic acid, para-hydroxybenzoic acid, catechin, chlorogenic acid, caffeic acid, para-coumaric acid, syringic acid, ferulic acid, salicylic acid, and kaempferol. The most abundant components were phenolic acids, with syringic acid having the highest concentration (0.44-6.61 mg per 100 g).

Table 6. Phenolic and flavonoid compounds contents of vegetarian bars for fitness athletes and its antioxidant activity

Bars		Phenolic compounds (mg GAE/100g)	Flavonoid compounds (mg Quercetin E/100g)	Antioxidant activity (%)
F1	Salty bars	$1179.29^{g} \pm 2.37$	$804.28^{f} \pm 2.44$	$85.45^{g} \pm 0.78$
F2		$911.35^{h} \pm 0.68$	$249.45^{h} \pm 1.43$	$84.23^{h} \pm 0.23$
F3		$1402.05^{e} \pm 1.55$	$1174.51^{c} \pm 2.43$	$90.25^{e} \pm 0.21$
F4		$1645.60^{c} \pm 0.64$	$1134.51^{d} \pm 0.81$	$91.88^{d} \pm 0.26$
F5		$1316.79^{f} \pm 0.78$	$710.46^{g} \pm 2.51$	$86.23^{f} \pm 0.44$
F6		$1480.15^{d} \pm 0.22$	$1449.92^{b} \pm 0.50$	$92.91^{c} \pm 0.19$
F7	Sweet bars	$2888.32^{b} \pm 1.33$	$1029.28^{e} \pm 1.85$	$94.12^{b} \pm 0.19$
F8		$3976.43^{a} \pm 0.70$	$1783.24^{a} \pm 1.80$	$95.86^{a} \pm 0.14$
BHA				$93.52^{bc} \pm 0.78$

Values are mean of three replicates ± SD, number in the same column followed by the same letter is not significantly different at 0.05 level.
F1: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F2: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F3: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F4: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F5: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F6: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F7: Yellow lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.
F8: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.
BHA: Butylated hydroxyanisole

These compounds also showed great promise as antioxidants. Based on these results, it is evident that the bars containing spirulina exhibit higher antioxidant activity compared to the bars containing sprouted lentils, with the exception of F5. Sadeghi et al. (2022) noted that spirulina is recognized for its performance-enhancing and antioxidant properties. There were no significant differences ($P \leq 0.05$) between F7 and F6 (94.12 and 92.91%, respectively) and the BHA sample (93.52%). Additionally, F8 and F7 demonstrated higher antioxidant activity (95.86 and 94.12%, respectively) than the BHA sample (93.52%), while F6, F4, and F3 had antioxidant activity values close to that of the BHA sample (92.91, 91.88, and 90.25%, respectively). On the other hand, the antioxidant activity values of the samples F5, F1, and F2 (86.23, 85.45, and 84.23%, respectively) were lower than that of the BHA sample (93.52%). Jovanov et al. (2021) found that bars prepared from whey protein isolate and soy protein isolate have a high antioxidant response and ability to improve physiological acclimation, especially after strenuous exercise.

Sensory evaluation of vegetarian bars for fitness athletes

The salty and sweet bar samples were subjected to sensory evaluation for color, flavor, taste, texture, appearance, and overall acceptability. The results are presented in Table **7**. Color scores ranged from 8.9 (F3) to 5.0 (F5). Bars containing spirulina had a darker color than those containing lentils, possibly due to the higher content of phenolic and flavonoid compounds in the spirulina bars (as shown in Table 6), which are closely related to color. Research by Pietta (2000) and Elham et al. (2006) has demonstrated a significant correlation between color levels and phenolic compound levels. No significant differences ($P \leq 0.05$) were observed between F3, F2, and F7, nor between F1 and F8, or between F6, F4, and F5. All color scores were 5 or higher, indicating that all bars were acceptable to the panelists. A similar trend was observed for flavor values. The flavor analysis revealed F3 had the highest score (8.9), followed by F7 (8.6) and F2 (8.3), with F4 scoring the lowest (5.6). There were no significant differences ($P \leq 0.05$) between F3, F7, and F2, nor between F1, F6, and F8, or between F5 and F4. Additionally, all the flavor values of the bars were higher than 5, indicating that they were well-received by the panelists. According to the flavor results, it was observed that bars containing lentils received higher scores from the panelists than bars containing spirulina. Concerning taste, it was observed that no significant differences ($P \leq 0.05$) between F3, F7, and F2, as well as between F1, F6, and F8, and also between F5 and F4. It was noted that the taste values ranged from 8.9 as in F3 to 5.6 as in F4. Also, based on the taste results, it was observed that bars containing lentils were preferred by the panelists over bars containing spirulina. However, taste values for all bars did not fall below 5, indicating that panelists accepted all the bars and did not reject any of them. In terms of texture, it is evident that there were no significant ($P \leq 0.05$) differences were found for the scores F7, F3, F2, and F1. Similarly, there were no significant ($P \leq 0.05$) differences in the texture scores between F6 and F8, as well as between F4 and F5. The texture values varied from 8.4 for F7 to 5 for F5. It is clear that, F7, F3, F2, and F1 were strongly liked, while F6 and F8 were moderately liked, and F4 and F5 were neither liked nor disliked. The appearance of the bars was in line with the other sensory aspects evaluated. The scores for appearance ranged from 8.4 for F3 to 5.6 for F5. The preference was clearly for the bars containing lentils rather than those containing spirulina. Furthermore, none of the bars were rejected, as all the appearance scores were higher than 5. Also, it was observed that no significant differences ($P \leq 0.05$) between F3, F7, and F2, as well as between F1, F8, and F6, and also between F4 and F5. Finally, In terms of overall acceptability, there were no significant differences ($P \leq 0.05$) between the bars F3, F2, F7, and F1. The same pattern was observed for F8, F6, and F4. However, F4 and F5 had the lowest scores and were found to be significantly different ($P \leq 0.05$) from the other bars, with no significant differences ($P \leq 0.05$) between them. The overall acceptability scores ranged from 9 for F3 to 6.5 for F5. In general, panelists did not reject any of the

($P \leq 0.05$) from the other bars, with no significant differences ($P \leq 0.05$) between them. The overall acceptability scores ranged from 9 for F3 to 6.5 for F5. In general, panelists did not reject any of the bars, meanwhile, bars F3, F2, F7, and F1 were extremely liked, while F8, F6, F4, and F5 were moderately liked. Also, the panelists consistently preferred salty bars containing sprouted lentils. Among these bars, they liked sesame seed bars the most, followed by flaxseed bars, and then chia seed bars. However, when evaluating bars containing spirulina, the panelists preferred sesame seed bars, followed by chia seed bars, and then flaxseed bars. It's worth noting that when considering both flavor and taste, the preferred order was sesame seed bars, followed by flaxseed bars, and then chia seed bars. Veggi et al. (2018) reported that Chia seeds positively affect the taste and texture of high-protein diet bars while providing an alternative method to enhance their nutritional value. Jovanov et al. (2021) found a high acceptance of a bar prepared with 24% whey protein isolate and 6% soy protein isolate as protein sources compared to commercial bars. Barmare and Battalwar (2023) found that bars containing spirulina and almonds covered in chocolate had higher taste and texture values and were more preferred and acceptable overall.

Table 7. Sensory evaluation of vegetarian bars for fitness athletes

Bars		Color (9)*	Flavor (9)	Taste (9)	Texture (9)	Appearance (9)	Over all acceptability (9)
F1	Salty bars	$7.9^{b} \pm 0.23$	$7.5^{b} \pm 0.26$	$7.9^{b} \pm 0.17$	$7.8^{a} \pm 0.20$	$7.4^{b} \pm 0.16$	$8.7^{a} \pm 0.15$
F2		$8.7^{a} \pm 0.15$	$8.3^{a} \pm 0.15$	$8.7^{a} \pm 0.15$	$8.1^{a} \pm 0.10$	$8.2^{a} \pm 0.13$	$8.9^{a} \pm 0.10$
F3		$8.9^{a} \pm 0.10$	$8.9^{a} \pm 0.10$	$8.9^{a} \pm 0.10$	$8.2^{a} \pm 0.13$	$8.4^{a} \pm 0.16$	$9.0^{a} \pm 0.01$
F4		$5.3^{c} \pm 0.21$	$5.6^{c} \pm 0.16$	$5.6^{c} \pm 0.22$	$5.4^{c} \pm 0.22$	$5.9^{c} \pm 0.10$	$6.8^{bc} \pm 0.20$
F5		$5.0^{c} \pm 0.21$	$6.0^{c} \pm 0.33$	$5.9^{c} \pm 0.27$	$5.0^{c} \pm 0.25$	$5.6^{c} \pm 0.16$	$6.5^{c} \pm 0.16$
F6		$6.6^{c} \pm 0.26$	$7.4^{b} \pm 0.30$	$7.4^{b} \pm 0.26$	$6.7^{b} \pm 0.26$	$7.1^{b} \pm 0.17$	$7.2^{b} \pm 0.24$
F7	Sweet bars	$8.6^{a} \pm 0.16$	$8.6^{a} \pm 0.16$	$8.9^{a} \pm 0.10$	$8.4^{a} \pm 0.16$	$8.4^{a} \pm 0.16$	$8.8^{a} \pm 0.13$
F8		$7.5^{b} \pm 0.22$	$7.2^{b} \pm 0.32$	$6.8^{b} \pm 0.20$	$6.5^{b} \pm 0.26$	$7.2^{b} \pm 0.29$	$7.4^{b} \pm 0.22$

Values are mean of twenty replicates ± SD, number in the same column followed by the same letter is not significantly different at 0.05 level.
F1: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F2: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F3: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F4: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F5: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F6: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F7: Yellow lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.
F8: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.
*where: 1=dislike extremely, 2= dislike very much, 3= dislike moderately, 4= dislike slightly, 5= neither like nor dislike, 6= like slightly, 7= like moderately, 8= like very much, and 9= like extremely.

Microbiological evaluation of vegetarian bars for fitness athletes

A microbiological study was conducted on salty and sweet bars to compare their storage at room temperature and 4°C. The results were summarized without tabulating. It was observed that no bacterial growth occurred on the plates for all bars until 7 weeks, but it started to appear in the 8th week and gradually increased until the 12th week, without exceeding the permissible limit (10^3cfu/g) according to the Egyptian standard specification (ES:2730/2007). Additionally, no

yeast and mold growth were observed until the 10th and 12th weeks. Furthermore, it was noted that the number of microorganisms in all samples of bars stored at room temperature was higher compared to those stored at 4°C. These results are in agreement with Singh et al. (2020), who found that the shelf life of chia seed bars was 28 days, after which there was an increase in the growth of microorganisms due to higher humidity levels. Additionally, Doiphode and Mane (2021) studied the effect of storage on the quality of spirulina snack bars and found that total plate counts and yeast/mold counts were not detected until 30 days of storage. Thereafter, an increasing trend was observed from day 45 to day 90 of storage at room temperature. They concluded that the protein-rich snack bars could be stored for 90 days in a polypropylene bag at room temperature. It was also observed that proteolytic bacteria, lipolytic bacteria, coliform bacteria, *staphylococcus aureus* and salmonella were not detected in any of the samples, consistent with findings reported by Opondo et al. (2022). These results are also in agreement with Trząskowska et al. (2022), who found that high protein bars could be stored for at least 3 months without detecting *staphylococcus aureus*, salmonella, or other pathogenic microorganisms. Barmare and Battalwar (2023) found that bars containing spirulina and almonds covered in chocolate stayed for 30 days without any change in shelf life or taste.

The percentages of coverage of the recommended daily allowances (RDA) by the different prepared vegetarian bars for fitness athletes

The RDA percentages for each 100g bar were calculated based on their chemical composition, compared with the standard RDA required for 80 kg males. The results are detailed in Table 8, providing valuable insights into the nutritional values of the bars. The standard RDA required for a male weighing 80 kg is 1.1-1.9 g of protein per kg body weight, 1 g of fat per kg body weight and 6-8 g of carbohydrates per kg body weight, according to National Policy and Resource Center on nutrition and adults, Florida International University, (2004), Pandey and Singh (2013) and Sygit (2016). The protein content in F1, F2, F3, F4, F5, and F6 bars was approximately the same, covering between 18.8% for F5 and 21.5% for F1, of the recommended daily allowance (RDA). However, F7 and F8 had lower protein content, covering between 11.1% for F8 and 12.7% for F7 of the RDA. Additionally, there were no significant differences ($P \leq 0.05$) in the RDA coverage % between F1 and F3, and between F4 and F2. The fat content of F1 to F7 covered 29.5% to 37.8% of the recommended daily allowance (RDA). F8 covered 40.8% of the required RDA from fat. Moreover, there were no significant differences ($P \leq 0.05$) in the RDA coverage % between F1 and F2, F4 and F5, and F3 and F6. The carbohydrate content ranged from 34.28% for F3 to 45.42% for F8, covering 6.1% to 8.1% of the recommended daily allowance (RDA). Importantly, there were no significant differences ($P \leq 0.05$) in the RDA coverage % for carbohydrates between F2 and F4, also between F5 and F6. Finally, the energy values of the prepared bars varied between 456.28 to 528.64 kcal/100g bar, and the coverage percentages of RDA ranged between 13.3-15.4%, respectively for 80 kg males. From these results, it could be observed that F7 and F8 showed the highest values of energy, which may be due to their composition, especially the presence of coconut, chocolate, date molasses, and molasses (refer to Table 1). These results unequivocally align with the recommendations of Amawi et al. (2024), emphasizing the need for athletes' diets to be rich in carbohydrates, with a recommended intake ranging from 3 to 12 grams per kilogram of body weight, depending on the type and duration of physical activity. The results are in line with the findings of Piątkowska et al. (2019), which examined optimal macronutrient levels for male and female athletes, regardless of amateur or professional status, during gym fitness training. The results are consistent with the findings of Barmare and Battalwar (2023), who highlighted that sedentary individuals should aim for 0.8 grams of protein per kilogram of body weight, while athletes

engaging in fitness activities may benefit from consuming between 1.5 to 2 grams of protein per kilogram of body weight, based on their age and the nature of their sports.

Table 8. The percentages of coverage of the recommended daily allowances (RDA) by the different prepared vegetarian bars (100 g) for fitness athletes

Bars		Protein (g)	RDA coverage (%)	Fat (g)	RDA coverage (%)	Carbohydrates* (g)	RDA coverage (%)	Caloric value (Kcal/100g)	RDA coverage (%)
F1	Salty bars	25.79^{a} ±0.69	21.5^{a}±0.02	23.61^{e}±0.17	29.5^{e}±0.01	37.20^{c}±0.06	6.6^{c}±0.02	464.45^{e}±0.70	13.5^{e}±0.02
F2		24.08^{bc}±0.06	20.1^{b}± 0.02	24.04^{e}±0.32	30.1^{e}±0.02	35.90^{d}±0.26	6.4^{d}±0.02	456.28^{f}±1.22	13.3^{f}±0.03
F3		25.12^{ab}±0.24	21.0^{a} ±0.03	28.35^{c}±0.02	35.4^{c}±0.01	34.28^{f}±0.05	6.1^{f}± 0.03	492.75^{c}±1.03	14.3^{c}±0.03
F4		24.58^{ab}±0.71	20.5^{b}±0.03	25.98^{d}±0.17	32.5^{d}±0.02	35.98^{d}±0.06	6.4^{d}± 0.02	476.06^{d}±1.74	13.8^{d}±0.02
F5		22.53^{d}±0.25	18.8^{d}±0.03	26.35^{d}±0.24	32.9^{d}±0.03	35.10^{e}±0.44	6.3^{e}± 0.03	467.67^{e}±1.35	13.6^{e}±0.02
F6		23.12^{cd}±0.06	19.3^{c}±0.04	29.07^{c}±0.64	36.3^{c}±0.02	35.04^{e}±0.36	6.3^{e}± 0.03	494.27^{c}±1.28	14.4^{c}±0.03
F7	Sweet bars	15.18^{e}±0.33	12.7^{e}±0.03	30.23^{b}±0.08	37.8^{b}±0.01	42.78^{b}±0.11	7.6^{b}± 0.01	503.91^{b}±1.74	14.6^{b}±0.01
F8		13.30^{f}±0.24	11.1^{f}±0.03	32.64^{a}±0.33	40.8^{a}±0.01	45.42^{a}±0.26	8.1^{a}± 0.01	528.64^{a}±0.65	15.4^{a}±0.01

Values are mean of three replicates ± SD, number in the same column followed by the same letter is not significantly different at 0.05 level; *Carbohydrates: was calculated by difference
F1: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F2: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F3: Sprouted lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F4: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, and chia seeds.
F5: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, flaxseeds and chili and lemon.
F6: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, salt, chia seeds, sesame seeds and ground cumin.
F7: Yellow lentils, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.
F8: Spirulina powder, pumpkin, water, yellow corn flour, peanut butter, peeled pumpkin seeds, chia seeds, date molasses, coconut, dark chocolate and molasses.

4. Conclusion

This study succeeded in producing eight different advanced and innovative ready-to-eat bars. These bars can be consumed before, during or after endurance sports or while on the go and travelling. It is produced from plant sources and spirulina. It is free from gluten, lactose, preservatives, artificial colors or sweeteners. Bars have been developed to be more nutritious, high in calories and less expensive than their commercial counterparts due to their high protein, fat and carbohydrate content. In addition, they contain different minerals and come in various flavors to suit vegetarians, athletes, individuals with gluten or lactose intolerance, and those following a fasting diet. They are also suitable for school children and individuals who need mental effort. The bars have high antioxidant activity which helped in extending the shelf life, and their protein content was found to be easily digestible and well accepted by the participants. These bars meet the preferences of many consumers and can meet a significant portion of the daily nutritional requirements of children, adolescents, adults and fitness enthusiasts.

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