International Journal of Nutrition and Food Sciences
2026, Vol. 15, No. 3, pp. 134–142
https://doi.org/10.11648/j.ijnfs.20261503.15

SciencePG
Science Publishing Group

Research Article

Design, Formulation, and Sensory Acceptability of Functional Energy Bars for Astronaut Nutrition

Hadiza Haruna Abdulrasheed*, Mariya Akilu, Abubakar Adamu, Leleji Jeffree, Abubakar Ciroma Ibrahim

Physical and Life Sciences Department, National Space Research and Development Agency, Abuja, Nigeria

Abstract

Energy bars are compact, nutrient-dense, shelf-stable foods with significant potential to reduce physiological decline during spaceflight. In long-duration missions, factors such as limited payload capacity, metabolic changes, bone demineralization, and radiation-induced oxidative stress require the development of specific functional countermeasures. The goal of this study was to create and test functional energy bars made from climate-resilient, plant-derived indigenous ingredients rich in essential macronutrients, micronutrients, and bioactive substances that would be suitable for future long-duration flight profiles. Raw materials were systematically cleaned, sorted, graded, and processed via controlled thermal roasting and precision milling to regulate moisture activity. Four distinct formulations (Samples A, B, C, and D) were developed by modulating the ingredient ratios to optimize caloric density, antioxidant defense, and structural integrity. The resulting composites were homogenized, molded, stabilized via controlled thermal setting (28°C for 6 hours), and portioned into standardized 40g square rations. Proximate composition, caloric density, and organoleptic viability were determined, with sensory acceptability evaluated via a 5-point hedonic scale. The developed formulations exhibited a mean caloric density of 216kcal per 40g serving, which aligns with the strict aerospace mass-to-energy constraints. Sensory data revealed that Formulations A and B achieved significantly higher scores for overall acceptability compared to formulations C and D. These findings demonstrate that precisely engineered energy bars derived from indigenous ingredients offer a palaTable, highly nutritious countermeasure for microgravity environments while providing high-performance applications on Earth.

Keywords

Energy Bars, Nutrient-dense, Functional Foods, Fortification, Sensory Properties, Space Environment

1. Introduction

In line with its mission, the National Space Research and Development Agency (NASRDA) has made significant strides toward joining other spacefaring countries in launching the first Nigerian astronaut into space. The Nigerian Astronaut Program has developed its space food program, which entails the development, production, and packaging of indigenous foods to meet the nutritional needs of Nigerian astronauts. Long-duration missions require foods that combine high nutrient density, long shelf life, minimal mass/volume penalty, accepTable sensory properties, and physiological benefits that

*Correspondence: Hadiza Haruna Abdulrasheed (hadizaabdulrasheed@gmail.com)

Received: 1 June 2026; **Accepted:** 16 June 2026; **Published:** 30 June 2026

may help counteract the effects of microgravity and space radiation. Reviews of space food systems highlight the need not only for macronutrients, vitamins, and minerals but also for bioactive non-nutrients (polyphenols, flavonoids, antioxidants) that may mitigate oxidative stress and inflammation [9].

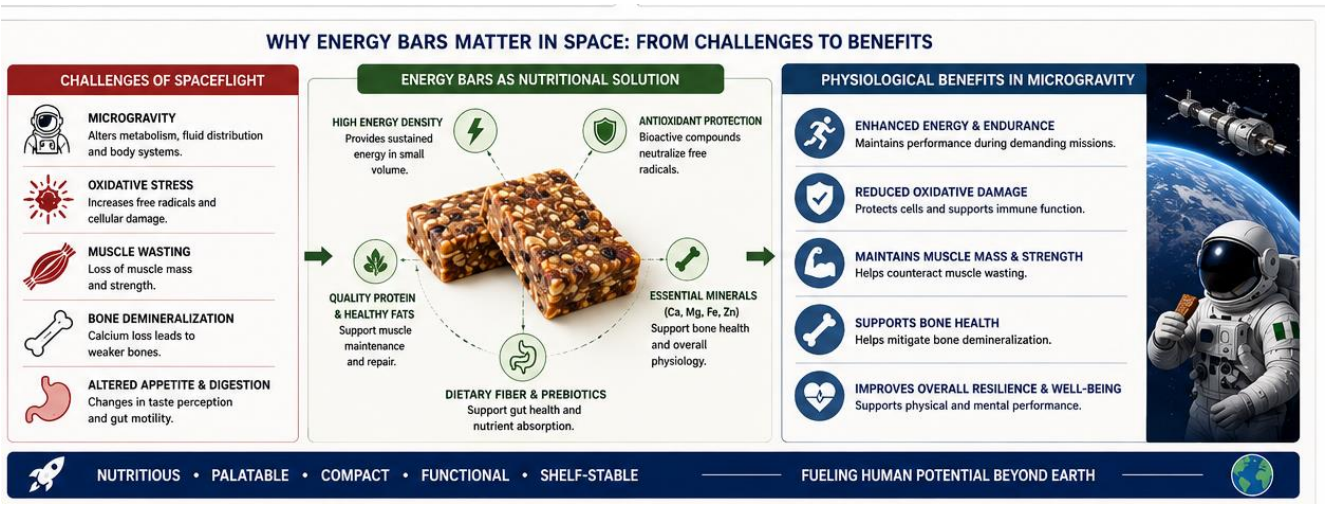

Figure 1. *Conceptual framework.*

Energy bars are supplemental food products containing cereals, micronutrients, and flavor ingredients intended to provide quick energy [6]. They are well-balanced, handy, and healthy snacks that provide appropriate nutrient proportions [21]. Historically, energy bars were engineered specifically for the aerospace sector as non-frozen, shelf-sTable snacks designed to provide astronauts with concentrated energy and essential nutrition. The bars were compact, slim, and easy to carry, so the astronauts used to keep them in their helmets. The energy bars later became popular amongst sportsmen, athletes, bodybuilders, and women for providing instant energy and enhancing their performances. Energy bars are prepared with a variety of nutritious ingredients, including cereals, rolled oats, dried fruits, nuts, seeds, and more. The bars come in multiple varieties and are known by various names, such as protein bars, granola bars, meal replacement bars, breakfast bars, health bars, and fruit bars [2]. Fruit bars are commonly favored for their delecTable flavor, texture, and simple packaging [21]. These days, there are hundreds of varieties of portable snack bars on the global market, including balanced, protein-enriched, cereal breakfast replacement, and brain-boosting bars [6]. The market for snack bars has expanded significantly over the last ten years; by 2025, it is predicted to reach USD 19 billion from USD 15 billion in 2019 [14].

Typically, an energy bar weighs between 30 and 50 g and provides about 200-300 Cal (840-1,300 kJ), 3-9 g of fat, 7-15 g of protein, and 20-40 g of carbohydrates. To provide energy quickly, most carbohydrates are in the form of sugars such as fructose, glucose, [4] and maltodextrins, and are combined with complex carbohydrate sources, such as oats or barley. Energy bars serve a wide variety of uses, including providing an energy source, serving as meal replacements in weight-loss diets, serving as snacks, and treating malnutrition [5]. Every fruit included in an energy bar enhances its own taste character and nutritional composition [19]. Protein-enriched fruit-based energy bars serve as a convenient snack to fulfil nutritional needs, enhance muscular development, and alleviate transient hunger [1]. Incorporating protein into food products provides consumers with healthier alternatives and health benefits [10]. Despite the countless formulations developed to date, certain bars available on the market still fail to attain a generally accepTable flavor. [18]. In the development of new food products, it is essential to enhance both sensory and functional attributes to ensure acceptability and superior quality. The premise was to obtain bars with elevated nutritional value. The objective of the study was to create high-energy bars using local organic products and health-promoting ingredients, like dried fruits, cereals, and nuts. The results from this study are expected to advance the development of a Nigerian Astronaut menu and address the evolving consumer demands.

1.1. Nutritional and Health Benefits of Ingredients Used in the Formulation

Cereals are grasses grown for their starchy, edible grains, which are a vital staple food globally. Oats, wheat, rice, oats, and maize are typical examples. Although they are frequently eaten as processed breakfast cereals, the word "cereal" also refers generally to the raw grains that are essential to both human and animal diets. Oats are rich in protein, dietary fiber, various B vitamins, and key minerals [24], with a 100 g serving providing approximately 389 calories. Consuming oat products regularly lowers blood levels of total cholesterol [23] and low-density lipoprotein [23, 24] and ultimately reduces

the risk of cardiovascular diseases [25]. Oats in a diet decrease blood lipids and lower the BMI in obese people [25].

The inclusion of cereals can substantially improve the nutritional profile of the energy bars, enhance the texture, and extend shelf life by absorbing moisture, thereby inhibiting microbial growth [2].

Nuts and seeds are rich in healthy proteins, fiber, lipids, vitamins, and minerals, which promote cardiovascular health by lowering blood pressure and cholesterol. This formulation contains almonds, sunflower seeds, which are rich in selenium, magnesium, and vitamin E, known to reduce oxidative stress and boost immunity, sesame seeds, flaxseed, which is loaded with omega-3 fatty acids that help reduce inflammation and promote heart health, and chia seeds, which are rich in antioxidants, omega-3s, and protein, which collectively boost energy. The fiber supports glycemic control and gastrointestinal function, while the satiating quality aids in weight management. Seeds are an important part of a well-balanced diet because of their rich antioxidant, phytochemical, and anti-inflammatory contents. Combining seeds with nuts such as almonds, walnuts, and cashews provides the quintessential sustained energy [12]. Nuts supply healthy fats and protein, whereas seeds contribute fiber and minerals, collectively offering a balanced and sustainable energy source. This combination not only sustains energy levels but also fulfills cravings healthily, diminishing the inclination to excessively indulge in fried or sugary foods [12].

Dried fruits like Mango, pineapple, and strawberries used in this energy bar are rich in carbohydrates, dietary fiber, and essential minerals such as potassium, magnesium, and iron. They also contain vitamins, notably B vitamins and variable vitamin C, and are concentrated sources of polyphenols and antioxidants [7, 26]. Their nutrient density per gram makes them advantageous in spaceflight, where mass and volume are limited. Dried fruits function as natural binders for ingredients while delivering an immediate and prolonged supply of rapidly digestible carbs, vital vitamins, and dietary fiber without dependence on refined sugars [3]. They impart a sticky, malleable consistency, and when incorporated into energy bars, they bind the oats, seeds, and nuts into cohesive bars, maintaining their form at ambient temperature [26]. Dried fruits include naturally occurring carbohydrates such as fructose and glucose, providing a rapid energy release [3]. This renders them optimal for pre-workout or intra-workout snacking, as muscles can swiftly use this glycogen for energy without the gastrointestinal discomfort frequently associated with commercial sports gels [3]. Due to their retention of natural dietary fiber, dried fruits mitigate rapid blood sugar fluctuations and subsequent declines. This generates a consistent flow of energy instead of the reactive hypoglycemia linked to refined sweets [3].

Figure 2. *Some ingredients used in the formulations.*

Natural sweeteners such as maple syrup and date syrup are increasingly studied as healthier alternatives to refined sugar in food formulations, including potential applications in space missions. [16]. Their appeal lies not only in their sweetness but also in their additional nutritional, functional, and sensory properties. Recent studies provide new insights into their chemical composition, health benefits, storage stability, and role in food product development. Maple syrup contains carbohydrates [11], primarily sucrose, along with phenolic compounds, organic acids, amino acids, and minerals such as potassium, calcium, zinc, and manganese [11, 17]. Its richer mineral and bioactive composition make it a more nutritionally advantageous choice than refined sugar [27]. Date syrup, depending on the variety, is rich in phenolic compounds [20], flavonoids, condensed tannins, and essential minerals. Recent profiling of Algerian date varieties [22] confirmed strong antioxidant activity linked to these bioactive compounds.

Functional additives, such as extracts from fruits, plants, or seeds, considerably enhance phytochemicals like phenolic acids and flavonoids, resulting in a substantial boost in the antioxidant capacity of the date bars [2]. Incorporating dry items like grains can augment protein content and accessibility. Oats can improve the amino acid profile, as cereals are recognized for their substantial fiber content, particularly due to their high-quality fibers, such as β-glucan [2]. Energy bars enriched with substantial quantities of minerals and vitamins can be produced through the incorporation of cereals.

Sensory qualities are critical determinants in the adoption of any newly developed food product. The use of flavor-intensive foods such as nuts and dried fruits, in addition to their nutritional benefits, can enhance the sensory appeal of date bars in terms of taste, flavor, aroma, and color [2]. The roasted components like cereals, dried fruits (mostly coconut flakes), and nuts markedly enhance the sensory characteristics of aroma, taste, and flavor. Nonetheless, the use of elevated temperatures may affect the bioavailability of certain micronutrients; therefore, these procedures should be performed at appropriate durations and temperatures [2].

1.2. Benefits of Energy Bars for Astronauts

1) Energy bars can serve as a sustainable, performance, and energy-dense meal option. A high calorie content (about 300-500 kcal per bar) is necessary for space missions where food mass and volume are restricted, since it delivers compact, lightweight energy.
2) The amount of macro- and micronutrients present in the energy bars can help improve healthy microbiomes, support the immune system of the astronauts, and also improve nutrient absorption.
3) The bars can help to maintain digestive health and bowel regularity, reducing constipation, which is a common problem for astronauts.
4) The ingredients used, like whole grains, seeds, nuts, and fruits, provide polyphenols, omega-3, and antioxidants, which help to reduce oxidative stress from space radiation and microgravity-induced inflammation.
5) The calcium and vitamin D present in the formulation can contribute to maintaining muscle mass and bone density, which are typically affected in microgravity.
6) Psychological and sensory benefits, having flavorful, chewy snacks provides comfort and variety, supporting mental health and morale on long missions.

2. Aim and Objectives

This study aims to design and formulate indigenous energy bars specially modified to provide the specific dietary requirements of astronauts, which will be achieved through the following objectives:

1) To identify indigenous Nigerian ingredients that can provide the nutritional needs of astronauts.
2) To design, formulate, and process the energy bar using specific space food criteria.
3) To carry out descriptive sensory evaluation for consumer acceptability of the energy bars.

3. Materials and Methods

The design and formulation of four (4) energy bar variants, consisting of different caloric and nutrient-dense ingredients, involved selecting locally grown ingredients based on their nutrient profiles, energy, and health benefits. The steps involved in the study are detailed below:

1) Selection, procurement, and preparation of ingredients.
2) Recipe formulations.
3) Processing and development of energy bars.
4) Sensory Evaluation.

3.1. Procurement and Preparation of Ingredients

The basic materials/Food produce were sourced from Utako food market in Abuja, while other ingredients were sourced from the grocery store in August, 2022. The seeds and nuts were cleaned, sorted, graded, and stored in glass jars. This was done quickly to avoid compositional and quality disparities.

3.2. Recipe Formulations

The recipes for the 4 energy bar variants were formulated by altering binding agents and ingredient proportions.

Table 1. Ingredients and formulated recipes for the 4 energy bars.

Ingredients	Scientific Name	Sample A	Sample B	Sample C	Sample D
Rolled oats	Avena sativa L.		✔	✔	✔
Maple syrup	-		✔		
Honey	-			✔	✔
Flaxseeds	Linum usitatissimum		✔	✔	✔
Chia seeds	Salvia Hispanica	✔		✔	✔
Almonds	Prunus dulcis		✔	✔	✔
Sunflower seeds	Helianthus annuus		✔	✔	✔
Coconut flakes	Cocos nucifera			✔	
Coconut almond butter	Cocos nucifera Prunus dulcis			✔	
Coconut oil	Cocos nucifera				✔
Dates	Phoenix dactylifera	✔	✔		
Dried fruits (Mango, Pineapple, Strawberry)	Mangifera indica Ananas comosus Fragaria x ananassa				✔
Sesame seeds	Sesamum indicum			✔	✔
Cashews	Anacardium occidentale		✔		
Raisins	Vitis vinifera	✔	✔		
Cranberries	Vaccinum oxycoccus	✔	✔		

Table 1 shows the ingredients used in each sample Energy bar variant.

3.3. Processing of Energy Bars

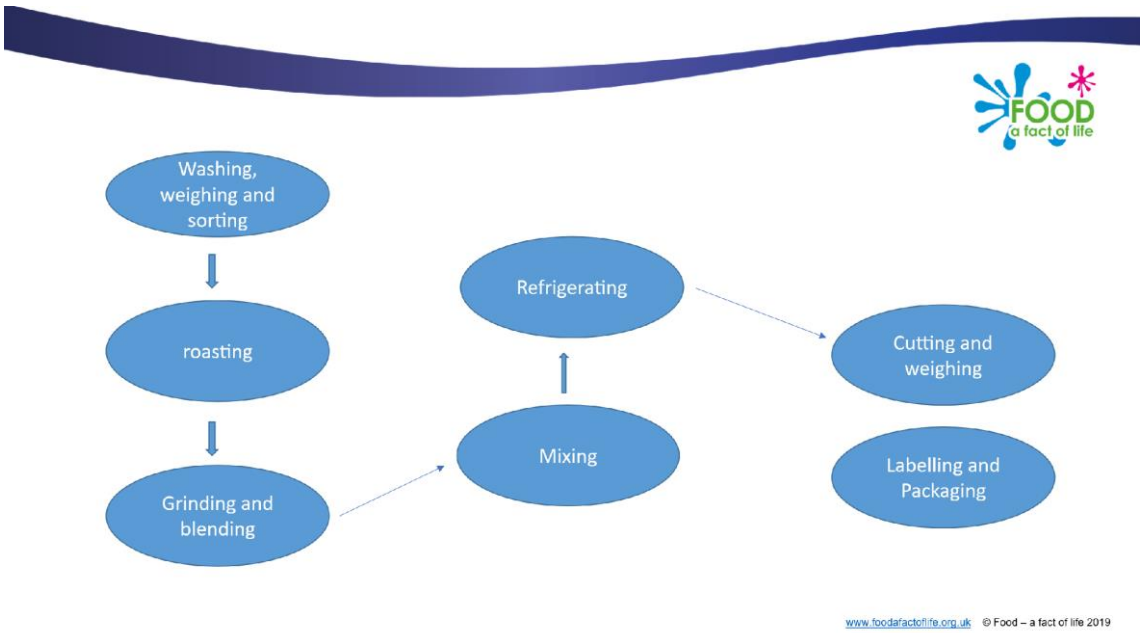

Figure 3. Preparation of Energy Bars.

The preparation of the energy bars followed a standardized protocol across four distinct formulations (Table 1). The process focused on texture optimization and ingredient integration through the following steps:

1) Pre-processing dry ingredients: Ingredients were sorted, washed, and weighed in preparation for processing. Oats were roasted for several minutes to enhance flavor and reduce moisture. Simultaneously, nuts and seeds were pulsed in a food processor to achieve a uniform particle size suitable for the bar's matrix.
2) Binding and homogenization: Sweeteners were incorporated into the dry mixture and blended thoroughly to ensure a homogenous, dough-like consistency and even nutrient distribution.
3) Molding and leveling: The composite mixtures were transferred to a glass baking pan and leveled with a spatula to maintain a consistent height and uniform density for the formulated bar.
4) Thermal stabilization: The molded dough was refrigerated for six hours at 28°C to set the structure and finalize the textural profile.
5) Cutting and weighing: The mixture was then separated into 40 square bars, each weighing about 40 g. Each of the four energy bar variants of 40g bar had a calorific content of about 216 kcal. Each bar was put in a sterile container and labelled before being used for sensory evaluation.

3.4. Sensory Evaluation of Energy Bars

As part of a single-blind sensory investigation, a convenience sample of the formulated energy bars was given to a group of participants from the life sciences department of NASRDA. The samples were labeled A, B, C, and D. With no prior knowledge of the contents of these bars, each participant had the opportunity to taste all four energy bars and provide their own comments based on their impressions. Using self-administered questionnaires, the sensory evaluation participants scored the acceptability of each energy bar based on appearance, taste, texture, and overall acceptability. Microsoft Excel was used to clean and code the data extracted from the questionnaires. Statistical software was then used to transcribe the coded data for descriptive analysis. Results of the descriptive analysis are included in the write-up.

4. Results and Discussion

Table 2. *Summarizes the sensory analysis findings in terms of hedonic ratings.*

5-Point Hedonic Rating Scale (40 panelists)								
Food characteristics	Appearance, Taste, Texture, Overall Acceptability							
	Sample A	Average	Sample B	Average	Sample C	Average	Sample D	Average
Appearance	190	4.8	181	4.5	152	3.8	132	3.6
Taste	183	4.6	171	4.3	163	4.1	132	3.6
Texture	184	4.6	173	4.3	151	3.8	155	4.3
Overall Acceptability	187	4.8	169	4.2	156	3.9	127	3.5
	Sample A	Sample B	Sample C	Sample D				
Appearance	4.8	4.5	3.8	3.6				
Taste	4.6	4.3	4.1	3.6				
Texture	4.6	4.3	3.8	4.3				
Overall Acceptability	4.8	4.2	3.9	3.5				

Table 2: 5-point Hedonic Record sheet for sensory evaluations

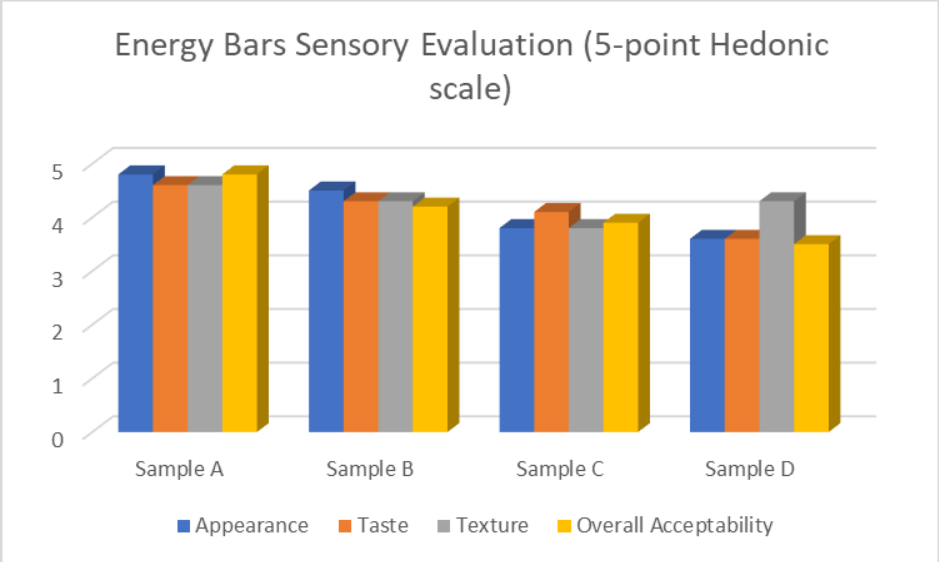

Figure 4. *Cumulative Sensory Evaluation of Energy Bars.*

Sensory or organoleptic evaluation is the examination of a food or non-food product based on the properties detecTable to the five human senses, such as fragrance, color, noise, taste, and texture [13]. Humans rely on their senses to receive information about food from the moment they see it until they consume it, and even thereafter, through retro-nasal odor and aftertaste [8]. Preference and hedonic tests are affective sensory tests that assess a product's approval among naive panelists. The hedonic assessment provides instant feedback on a newly created product's capability and likelihood of success [15].

The Table demonstrates that Sample A represents the most optimized formulation from a sensory standpoint, achieving superior performance across all evaluated parameters. Sample B may serve as a viable alternative with accepTable quality, whereas Samples C and D would require further formulation adjustments to improve their sensory profiles. These findings underscore the importance of balancing multiple sensory attributes in product development, as deficiencies in a single parameter can significantly influence overall acceptability.

5. Conclusion

The design and formulation of these energy bars, tailored specifically for Nigerian astronauts, represents a significant advancement in the development of indigenous space-grade nutrition. The results of the present investigation indicate that Sample A was the most preferred among the sensory evaluation panelists, achieving the highest scores for appearance, taste, texture, and overall acceptability. However, Samples B, C, and D exhibited a more diverse profile of ingredients and superfoods, making them higher in nutritive value. These formulations may offer superior physiological benefits, particularly in supporting gut health, a critical consideration for maintaining the microbiome in extreme microgravity environments. Strategies for developing a balanced, nutrient-rich, and effective energy bar with appealing sensory attributes for consumers, including the elderly, children, and athletes, are in progress.

6. Recommendations for Future Considerations

To ensure the viability of these energy bars for long-duration space missions, the following research and development priorities are identified:

1) Extended Stability Testing: A comprehensive shelf-life study is required to establish the precise duration for which the bars remain safe and nutritionally intact. The assessment would evaluate the product's resilience against degradation over time under simulated mission conditions.
2) Caloric Optimization: The formulation would be refined and adjusted to increase caloric density. Optimizing energy content is essential to support the high metabolic requirements of astronauts while minimizing the total mass of the food payload.

Abbreviations

NASRDA	National Space Research and Development Agency

Author Contributions

Hadiza Haruna Abdulrasheed: Conceptualization, Data curation, Formal Analysis, Project administration, Software, Supervision, Validation, Writing – review & editing

Mariya Akilu: Conceptualization, Data curation, Formal Analysis, Methodology, Resources, Software, Validation,

Writing – original draft

Abubakar Adamu: Data curation, Formal Analysis, Investigation, Resources

Leleji Jeffree: Data curation, Investigation, Methodology, Resources

Abubakar Ciroma Ibrahim: Data curation, Investigation, Methodology, Resources

Conflicts of Interest

The authors hereby declare that no conflicts of interest exist.

References

[1] AlJaloudi R, Al-Dabbas M, Hamad H, Amara R, Al-Bashabsheh Z, Abughoush M, Iqbal S. Development and Characterization of High-Energy Protein Bars with Enhanced Antioxidant, Chemical, Nutritional, Physical, and Sensory Properties. *Foods*. 2024; 13: 259. https://doi.org/10.3390/foods13020259

[2] Barakat H, Alfheeaid HA. Date Palm Fruit (*Phoenix dactylifera*) and its Promising Potential in Developing Functional Energy Bars: Review of Chemical, Nutritional, Functional, and Sensory Attributes. *Nutrition and Public Health*. 2023; 7: 2134. https://doi.org/10.3390/nu15092134

[3] Bhatt S. Dried Fruits, Nuts, and Seeds Energy Bars. *TheRoute2roots*. Published March 15, 2026. Available from: https://www.theroute2roots.com/dried-fruits-nuts-energy-bars/ [Accessed May 29, 2026].

[4] Cleveland Clinic. How to Choose the Best Health Bars. *Diet, Food & Fitness/Nutrition*. Published May 19, 2025. Available from: https://health.clevelandclinic.org [Accessed May 29, 2026].

[5] Coello K, Frias J, Martinez-Villaluenga C, Cartea M, Velasco P, Penas E. Manufacture of healthy snack bars supplemented with moringa sprout powder. *LWT - Food Science and Technology*. 2022; 154: 112701. https://doi.org/10.1016/j.lwt.2021.112828

[6] Gill A, Singh AK. Energy Bars: Quick, healthy, and wholesome snacks for Adolescents. *EARDA Publications / Traditional Lifestyle and Adolescents*. 2019; 4: 45-52. ISBN 978-81-941704-3-3. https://www.researchgate.net/publication/370059445

[7] Gonzalo Miranda M, Ángel B, Antonio M. Dried-Fruit Storage: An Analysis of Package Headspace Atmosphere. *Foods*. 2019; 8(3): 56. https://doi.org/10.3390/foods8020056

[8] Ilic J, Djekic I, Tomasevic I, Oosterlinck F, van den Berg MA. Materials properties, Oral Processing, and Sensory Analysis of Eating Meat and Meat Analogs. *Annual Review of Food Science and Technology*. 2022; 13: 193-215. https://doi.org/10.1146/annurev-food-090821-032332

[9] Menglan Z. Food Systems for long-term spaceflight: Understanding the role of non-nutrient polyphenols in astronauts' health. *Food Science and Nutrition*. 2024; 12: 37452. https://doi.org/10.1016/j.heliyon.2024.e37452

[10] Mercado PV, Mojica P, Morales H. Protein Ingredients in Bread: Technological, Textural and Health Implications. *Foods*. 2022; 11: 2399. https://doi.org/10.3390/foods11162399

[11] Mohammed F, Sibley P, Abdulwali N, Guillaume D. Nutritional, pharmacological, and sensory properties of maple syrup: A comprehensive review. *Journal of Food Biochemistry*. 2023; 47: 19216. https://doi.org/10.1016/j.heliyon.2023.e19216

[12] Nourish Organics. The Role of Nuts & Seeds in Keeping Your Energy High During Festivities. *Nourish Organics*. Published October 10, 2025. Available from: https://nourishorganics.in/blogs [Accessed May 29, 2026].

[13] Piana M, Oddo LP, Bentabol A, Bruneau E, Bogdanov S, Declerck CG. Sensory Analysis Applied to Honey: State of the Art. *Apidologie*. 2004; 35: 26-37. https://doi.org/10.1051/apido:2004048

[14] Research and Markets. Snack Bar Market Forecasts from 2020 to 2025. Dublin: Research and Markets; 2023. https://www.researchandmarkets.com/reports/6240836

[15] Ruiz-Capillas C, Herrero AM, Pintado T, Delgado-Pando G. Sensory Analysis and Consumer Research in New Meat Products. *Foods*. 2021; 10: 429. https://doi.org/10.3390/foods10020429

[16] Saraiva A, Carrascosa C, Ramos F, Raheem D, Lopes M, Raposo A. Maple Syrup: Chemical Analysis and Nutritional Profile, Health Impacts, Safety and Quality Control, and Food Industry Applications. *International Journal of Environmental Research and Public Health*. 2022; 19: 13684. https://doi.org/10.3390/ijerph192013684

[17] Saravanan G, Yusri AS, Sarbon N. Investigation of the Nutritional Value, Physicochemical Properties, Antioxidant Activity, and Sensory Acceptability of Fiber- and Protein-enriched Fruit-based Energy Bars. *Food Chemistry Advances*. 2026; 4: 101196. https://doi.org/10.1016/j.focha.2025.101196

[18] Szydlowska A, Zielinska D, Lepecka A, Trzaskowska M, Neffe-Skocinska K, Kolozyn-Krajewska D. Development of Functional High-Protein Organic Bars with the Addition of Whey Protein Concentrate and Bioactive Ingredients. *Agriculture*. 2020; 10: 390. https://doi.org/10.3390/agriculture10090390

[19] Tastan O. Effect of Dietary Fiber Enrichment on Quality Characteristics and Consumer Acceptance of Fruit Snacks. *Akademik Gida*. 2023; 21: 343-352. https://doi.org/10.24323/akademik-gida.1422812

[20] Temessek B, Rebai O, Sulli M, Abdallah B, Diretto G, Fattouch S. Synergizing tradition and innovation: Fortification of milk kefir with date syrup, a novel functional beverage. *Acta Alimentaria*. 2024; 53: 120. https://doi.org/10.1556/066.2024.00120

[21] Yadav L, Bhatnagar V. Optimization of Ingredients in a Cereal Bar. *Food Science Research Journal*. 2015; 6: 273-278. https://doi.org/10.15740/has/fsrj/6.2/273-278

[22] Zeroual S, Gaouaoui R, Deghima A. Polyphenolic Profile and in-vitro Antioxidant activity of Three Algerian Date (*Phoenix dactylifera*) varieties. *Journal of Agricultural Sciences*. 2024; 29: 112-121. https://doi.org/10.29133/yyutbd.1392549

[23] Schoeneck M, Iggman D. Beyond the Classical Nutrients: The Role of Dietary Phytochemicals and Bioactives in Chronic Disease Prevention. *Nutrition Reviews*. 2021; 79(11): 1223-1241. https://doi.org/10.1016/j.numecd.2020.12.032

[24] Whitehead A, Beck EJ, Tosh SM, Wolever TM. Cholesterol-lowering effects of oat β-glucan: a meta-analysis of randomized controlled trials. *The American Journal of Clinical Nutrition*. 2014; 100(6): 1413-1421. https://doi.org/10.3945/ajcn.114.086108

[25] Llanaj E, Dejanovic M, Valido E, Bano A, Gamba M, Aguiar M, Muka T. Effect of dietary phytochemicals on cardiovascular health: A systematic review and meta-analysis of randomized controlled trials. *European Journal of Nutrition*. 2022; 61(7): 3315-3331.

[26] Petcu F, Sibley P, Abdulwali N, Guillaume D. Nutritional, pharmacological, and sensory properties of dehydrated tropical fruits: A comprehensive review. *Journal of Food Composition and Analysis*. 2023; 115: 104921.

[27] Phillips KM, Carlsen MH, Blomhoff R. Total antioxidant content of alternatives to refined sugar. *Journal of the American Dietetic Association*. 2009; 109(1): 64-71. https://doi.org/10.1016/j.jada.2008.10.014

Research Field

Hadiza Haruna Abdulrasheed: Food product development, Functional foods, Space nutrition, Space Life Sciences, Food processing and preservation, Sustainable food systems

Mariya Akilu: Space Human Physiology and Health, Space Medicine, Public Health and Epidemiology, Food Biochemistry, Space Nutrition, Space Life Sciences, and Food Product Development

Abubakar Adamu: Space Life Sciences, Space Medicine, Pharmacognosy and Drug Development, Pharmacy, Space Human Health and Physiology, and Space Nutrition

Leleji Jeffree: Space Life Sciences, Radiation Biology, Space Health, Biochemistry, Space Physiology, and Space Nutrition

Abubakar Ciroma Ibrahim: Space Life Sciences, Space Health, Space Agriculture, Sustainable food systems, and Advanced food processing techniques