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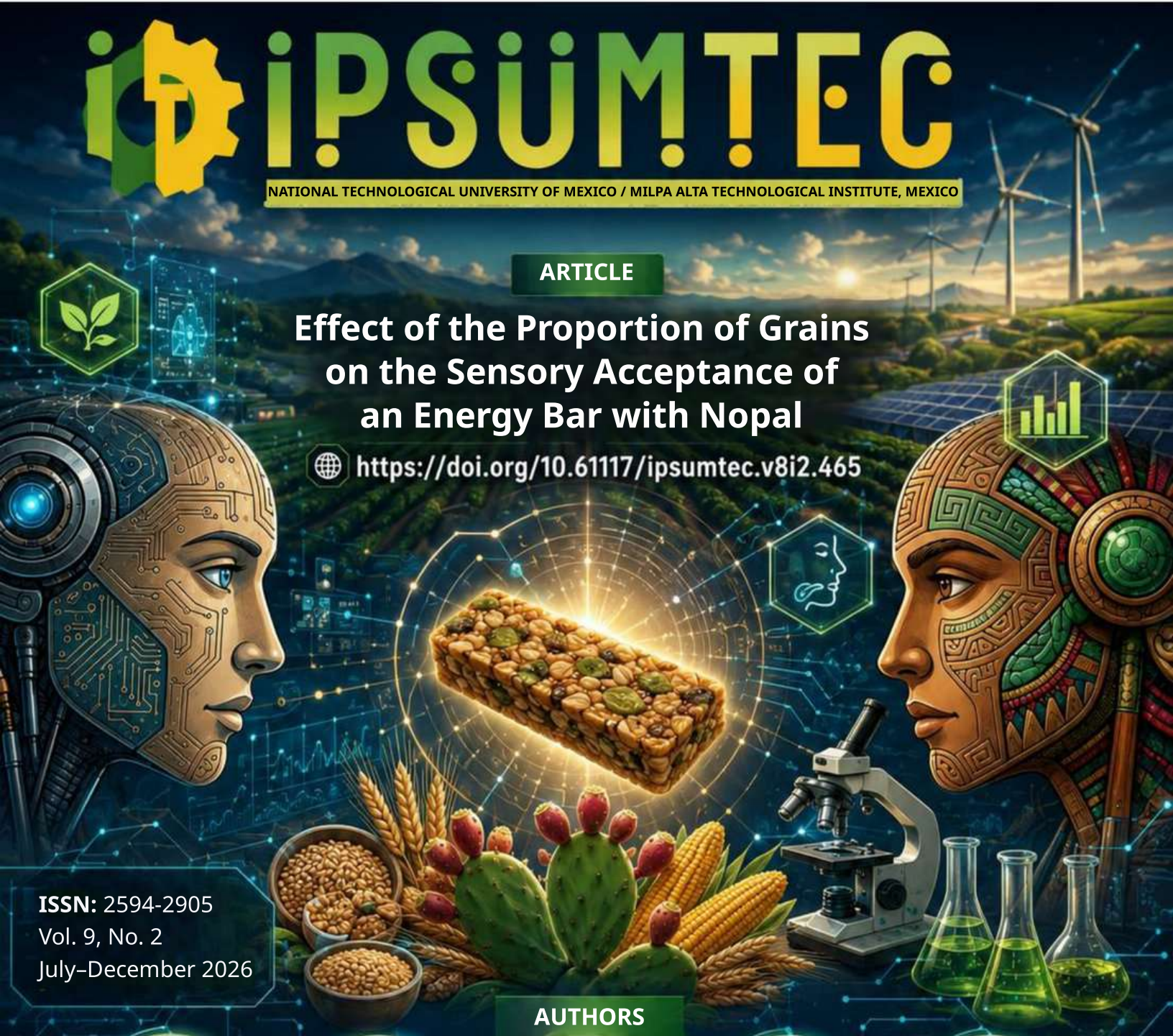
ARTICLE

Effect of the Proportion of Grains on the Sensory Acceptance of an Energy Bar with Nopal

https://doi.org/10.61117/ipsumtec.v8i2.465



ISSN: 2594-2905
Vol. 9, No. 2
July–December 2026

AUTHORS

Nancy Patricia Meade Almazán

Bertha Yadira Elizondo Nolazco

Claudia Cárdenas Vega

Susana del Carmen Torres Morales

Patricia Aidé Fernández García

EDUCATION
MINISTRY OF PUBLIC EDUCATION

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EDUCATION

IPSUMTEC
ISSN: 2594-2905

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https://doi.org/10.61117/ipsumtec.v9i2.471

AUTHOR INFORMATION AND IDENTIFICATION

Nancy Patricia Meade Almazán [1*], Bertha Yadira Elizondo Nolazco [2], Claudia Cárdenas Vega [3], Susana del Carmen Torres Morales[4], Patricia Aide Fernández García [5]

1	*Nancy Patricia Meade Almazan* *National Technological Institute of Mexico/I. T. de Linares, Mexico* ✉ nmeade@linares.tecnm.mx (Corresponding author) *ORCID: https://orcid.org/0000-0002-1698-3262*
2	*Bertha Yadira Elizondo Nolazco* *National Technological Institute of Mexico/I. T. de Linares, Mexico* ✉ belizondo@linares.tecnm.mx *ORCID: https://orcid.org/0000-0002-2807-3215*
3	*Claudia Cárdenas Vega* *National Technological Institute of Mexico/I. T. de Linares, Mexico* ✉ ccardenas@linares.tecnm.mx *ORCID: https://orcid.org/0000-0002-3649-4896*
4	*Susana del Carmen Torres Morales* *National Technological Institute of Mexico/I. T. de Linares, Mexico* ✉ storres@linares.tecnm.mx *ORCID: https://orcid.org/0000-0002-3394-6199*
5	*Patricia Aide Fernández García* *National Technological Institute of Mexico/I. T. de Linares, Mexico* ✉ pfernandez@linares.tecnm.mx *ORCID: https://orcid.org/0009-0000-7314-5911*

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Discipline:	*[X] Technology Management and Industrial Innovation*

ABSTRACT

To evaluate the sensory acceptance of an energy bar made with nopal (Opuntia ficus-indica) and different proportions of grains using a verbal hedonic test administered to potential consumers in the sports sector. Currently, the development of functional foods represents one of the main trends in the food industry due to growing consumer interest in nutritious, convenient products with potential health benefits. Energy bars are a widely accepted food alternative among physically active individuals and consumers who require foods that provide rapid energy. In this context, nopal (Opuntia ficus-indica) stands out for its dietary fiber, bioactive compounds, and minerals, while grains such as rice and rolled oats provide complex carbohydrates and energy. A completely randomized design with three treatments and five replicates was used, varying only the proportion of puffed rice and rolled oats. Sensory evaluation was conducted using a nine-point hedonic scale administered to a panel of potential consumers. The results showed that the treatment consisting of 70% puffed rice and 25% rolled oats exhibited the highest level of sensory acceptance, obtaining an average score of 1.8 on the hedonic scale, corresponding to the categories "I like it very much" and "I like it a lot." Furthermore, this treatment exhibited the lowest variance and standard deviation, indicating greater consistency in the evaluators' responses. It is concluded that the selected formulation has high

Date of Receipt: 04/06/2026 | Date of Acceptance: 06/12/2026 | Publication Date: 07/15/2026

sensory acceptability and represents a viable alternative for the development of functional food products aimed at physically active consumers, by combining ingredients with nutritional value and high consumer acceptance.

Keywords: *Functional foods, sensory analysis, oats, cereals, nopal, food products.*

ABSTRACT

To evaluate the sensory acceptance of an energy bar formulated with cactus pear (Opuntia ficus-indica) and different proportions of cereals using a verbal hedonic test administered to potential consumers in the sports sector. The development of functional foods has become one of the leading trends in the food industry due to increasing consumer demand for nutritious, convenient products with potential health benefits. Energy bars are widely accepted as practical food alternatives for physically active individuals who require readily available energy. In this context, cactus pear (Opuntia ficus-indica) is recognized for its high dietary fiber, bioactive compounds, and mineral content, whereas cereals such as puffed rice and rolled oats provide complex carbohydrates and energy. A completely randomized design with three treatments and five replicates was used, varying only the proportion of puffed rice and rolled oats. Sensory evaluation was conducted using a nine-point hedonic scale with consumer panelists. The formulation containing 70% puffed rice and 25% rolled oats achieved the highest sensory acceptance, with an average hedonic score of 1.8, corresponding to the categories "like extremely" and "like very much." This treatment also showed the lowest variance and standard deviation, indicating greater consistency in consumer responses. The selected formulation demonstrated high sensory acceptability and represents a promising alternative for the development of functional food products aimed at physically active consumers by combining ingredients with nutritional value and excellent consumer acceptance.

Keywords: *Functional foods, sensory analysis, oats, cereals, prickly pear (Opuntia ficus-indica), food products.*

INTRODUCTION

In recent years, the demand for functional foods has grown significantly worldwide due to consumer interest in products that, in addition to providing essential nutrients, contribute to well-being and the prevention of chronic diseases. This trend has driven the development of innovative foods formulated with natural ingredients rich in bioactive compounds, especially those targeted at physically active individuals and consumers with dynamic lifestyles [1], [2], [19]. In this context, energy bars have gained prominence as practical, portable products that provide quick energy, made primarily from grains, seeds, and dried fruits, which supply complex carbohydrates, dietary fiber, and antioxidants [3], [13], [16].

The development of functional energy bars currently represents one of the main areas of innovation in the food industry, as these products aim to simultaneously meet nutritional, sensory, and convenience needs. Several studies have shown that incorporating plant-based ingredients with antioxidant properties and high fiber content can improve the nutritional value of these products without compromising their sensory acceptability [4], [5], [18]. Furthermore, the use of regional and sustainable raw materials is an important strategy for diversifying the food supply and promoting the use of agri-food resources with functional potential [1], [19].

The nopal (Opuntia ficus-indica) is a cactus widely recognized for its nutritional and functional value. Its composition includes dietary fiber, phenolic compounds, vitamins, minerals, and antioxidants that have been associated with health benefits, such as glycemic control, cholesterol reduction, and improved gastrointestinal health [6], [7]. Furthermore, research

Recent studies indicate that the nopal cactus possesses antioxidant and prebiotic properties and is rich in bioactive compounds that support the development of functional foods with potential industrial applications [8], [9], [14], [17]. Due to these properties, the nopal cactus has sparked scientific and technological interest for its incorporation into various functional food products, including beverages, flours, snacks, and energy bars [7], [9].

Furthermore, cereals are an important source of energy in the human diet and are key ingredients in the formulation of energy bars. Puffed rice provides a light texture, volume, and an immediate source of carbohydrates, while oats are known for their content of β-glucans, antioxidants, and soluble fiber, which are associated with positive effects on cardiovascular and metabolic health [4], [10]. Furthermore, the proportion of cereals used in a formulation directly influences the physical and sensory properties of the final product, particularly attributes such as texture, flavor, appearance, and overall acceptability. Previous studies report that changes in cereal proportions can lead to significant differences in the hardness, cohesiveness, and crunchiness of energy bars, affecting consumer preference [11], [13], [16].

Sensory acceptance is one of the most important factors in the commercial success of new food products, since a food with high nutritional value may be rejected by consumers if it does not have pleasant organoleptic characteristics. Therefore, sensory evaluation is an essential tool in the development and optimization of functional foods. Among the most widely used methodologies is the verbal hedonic test, which measures the degree of consumer liking or disliking using structured acceptance scales [12], [18]. Similarly, recent research on energy bars enriched with functional ingredients indicates that texture and flavor are key factors in the product's sensory acceptance [5], [11].

Dietary fiber found in functional grains and vegetables plays an important role in the formulation of healthy foods due to its positive effects on digestion, gut microbiota, and metabolic health [20], [14]. In this regard, the combined use of nopal and grains represents a viable alternative for designing energy bars with functional properties and added value.

Despite growing interest in the development of functional foods made with natural ingredients, there is limited information on the influence of different cereal proportions on the sensory acceptance of energy bars made with nopal. This situation highlights the need for research to optimize formulations that strike an appropriate balance between nutritional value, technological properties, and consumer acceptance. Furthermore, previous studies on energy bars made with nopal have highlighted the importance of evaluating the texture and sensory acceptability of these products [15].

Research Questions

What proportion of puffed rice and rolled oats results in the highest sensory acceptance in an energy bar made with nopal?

How does the proportion of cereals influence the sensory characteristics of a functional energy bar made with nopal?

Research Hypothesis (H_1):

Variations in the ratio of puffed rice to rolled oats significantly influence the sensory acceptance of an energy bar made with nopal.

Null hypothesis (H_0):

Variations in the ratio of puffed rice to rolled oats do not significantly influence the sensory acceptance of an energy bar made with nopal.

Therefore, the objective of this study was to determine the combination of puffed rice and rolled oats with the highest sensory acceptance in a nopal-based energy bar using a verbal hedonic test.

METHODOLOGY

Generative AI Statement

During the academic writing and editorial revision of the manuscript, ChatGPT (OpenAI, GPT-5.5 version) was used to assist with style review, section organization, and grammatical correction. The authors verified the accuracy, consistency, and truthfulness of all information presented in the study.

Responsibility

The authors declare that the data presented are accurate and correspond to experimentally obtained results, guaranteeing the absence of alterations, intentional biases, or fabrication of information.

Research Design

This study was experimental, quantitative, and descriptive in nature. A completely randomized design was used with three treatments and five replicates per treatment. The independent variable was the proportion of puffed rice and rolled oats used in the energy bar formulation, while the dependent variable was the level of sensory acceptance obtained through a verbal hedonic test administered to potential consumers.

Sample Justification

The sensory evaluation was conducted with potential consumers from the local sports community. Fifteen untrained panelists participated, selected through non-probabilistic convenience sampling, with inclusion criteria based on being physically active and potential consumers of energy bar-type products. The sample size was considered adequate for an exploratory study of sensory acceptance aimed at identifying preference trends among formulations.

Evaluation Instrument

A verbal hedonic test was administered using a structured nine-point scale, where a score of 1 corresponded to “I like it very much” and a score of 9 to “I dislike it very much.” The nine-point hedonic scale is widely used and validated in sensory acceptance studies of functional foods due to its ease of application, reliability, and ability to measure consumer preferences [12], [18].

Sensory Evaluation Conditions

The sensory evaluation was conducted in a specially equipped area at the Linares Institute of Technology under appropriate lighting and ventilation conditions and with minimal interference from external odors. The samples were presented at room temperature in individual containers and identified using random three-digit codes to avoid biases related to visual identification or prior preferences of the panelists. Prior to the evaluation, participants received general instructions on the use of the verbal hedonic scale and on the importance of evaluating attributes related to overall acceptability, flavor, texture, and appearance of the product. Between each sample, panelists cleansed their palates by drinking water to minimize sensory interference between treatments. The evaluation was conducted individually to avoid influence among participants and ensure greater objectivity in the responses obtained.

Experimental Procedure

The energy bar was prepared at the Linares Institute of Technology using nopal, sugar, glucose, and tomato peel as the main ingredients for the base syrup. The syrup was then mixed with puffed rice, rolled oats, toasted walnuts, raisins, and ground ginger. The experimental variations focused exclusively on the proportion of cereals used. The treatments evaluated are shown in Table 1.

Table 1. *Experimental design of the treatments evaluated.*

Ingredient	Treatment 1	Treatment 2	Treatment 3
Toasted walnut	3%	3%	3%
Puffed rice	80%	70%	60%
Rolled oats	15%	25%	35%
Raisins	2%	2%	2%
Ground ginger	Minimum quantity	Minimum quantity	Minimum quantity

Source: *Prepared by the author*

The experimental procedure consisted of the following stages:

1. Preparation of the samples corresponding to each treatment.
2. Preparation and setup of the sensory evaluation area.
3. Random coding of the samples to avoid identification bias.
4. Random presentation of the samples to the panelists.
5. Recording of responses using the verbal hedonic scale.
6. Organization and statistical analysis of the data obtained.
7. Statistical analysis

The data obtained were analyzed using descriptive statistics with Microsoft Excel 2019® (Microsoft Corporation, United States). The mean, standard deviation, variance, and 95% confidence intervals were calculated for each treatment to identify the formulation with the highest sensory acceptance and the lowest dispersion in the evaluators' responses. Due to the exploratory nature of the study and the small sample size, no inferential tests were performed.

Methodological Limitations

The main limitation of the study was the small sample size and the use of non-probabilistic convenience sampling, which may limit the generalizability of the results to other population groups. Furthermore, the sensory evaluation was conducted only with physically active potential consumers from a specific locality; therefore, future research should consider larger and more heterogeneous samples.

RESULTS

The results revealed differences in the degree of sensory acceptance among the treatments evaluated.

As shown in Table 2, the treatments evaluated exhibited differences in the sensory acceptance ratings recorded by the panelists. Treatment 2 showed greater uniformity in the ratings obtained, with values concentrated between 1 and 3 on the hedonic scale, while Treatment 1 exhibited greater variability in the ratings, reaching values as high as 6. Treatment 3, meanwhile, recorded intermediate scores, although with lower acceptance compared to Treatment 2. These results demonstrated that the proportion of puffed rice and rolled oats influenced the sensory perception of the energy bars made with nopal.

Table 2. *Average results per repetition.*

Processing	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5
Treatment 1	1	3	6	3	1
Treatment 2	1	2	2	1	3
Treatment 3	5	5	2	2	2

Source. *Prepared by the authors.*

As shown in Table 3, Treatment 2 had the lowest mean score on the hedonic scale (1.8), indicating greater sensory acceptance by consumers. Furthermore, this treatment showed the lowest standard deviation and variance, indicating greater homogeneity in the panelists' responses.

Table 3. *Statistical results by treatment.*

Treatment	Mean	Standard Deviation	Variance	95% CI
Treatment 1	**2.8**	**2.05**	**4.20**	**0.26 – 5.34**
Treatment 2	**1.8**	**0.84**	**0.70**	**0.76 – 2.84**
Treatment 3	**3.2**	**1.64**	**2.70**	**1.17 – 5.23**

Source. *Author's own work.*

The 95% confidence intervals showed less dispersion in Treatment 2 compared to the other treatments, suggesting greater consistency in the sensory acceptance of this formulation.

As shown in Figure 1, the final product had a uniform appearance suitable for sensory evaluation, with a homogeneous distribution of the ingredients used in the energy bar formulation. Furthermore, the resulting structure allowed for the identification of characteristics related to texture, cohesiveness, and visual presentation—attributes that directly influence consumer acceptance. The selected formulation showed

structural stability and an appearance compatible with functional snack-type food products.



Figure 1. *Product ready for sensory evaluation.*

Source. *Author's own work.*

DISCUSSION

The results showed that the proportion of grains used in the formulation directly influenced the sensory acceptance of the energy bars made with nopal. Treatment 2, consisting of 70% puffed rice and 25% rolled oats, showed the highest level of consumer acceptance, suggesting that a balanced proportion of both cereals enhances sensory attributes such as texture, flavor, and overall acceptability.

These results support the research hypothesis, as the variation in the proportion of puffed rice and rolled oats did influence the sensory perception of the product. The higher acceptance observed in Treatment 2 can be attributed to the fact that oats, in moderate proportions, provide smoothness, cohesiveness, and a pleasant mouthfeel, while puffed rice contributes crunchiness, lightness, and an improved perception of texture. Previous research has indicated that oats improve the functional and sensory profile of food products due to their content of β-glucans, soluble fiber, and antioxidant compounds [4], [10]. However, high concentrations of oats can result in denser products or a pasty mouthfeel, reducing consumer acceptability [11], [16]. This is consistent with the results obtained in Treatment 3, where an increase in rolled oats was associated with lower sensory acceptability.

Likewise, puffed rice played an important role in the product's physical properties, as it contributed to a lighter structure and a crispier texture. Several authors have reported that this ingredient increases the perception of freshness and improves the chewiness of energy bars and functional snacks [13], [16]. In the present study, the treatments with higher puffed rice content showed better texture perception, although excessive proportions could affect the bar's cohesiveness and structural stability.
Furthermore, the use of nopal as a functional ingredient represents an innovative alternative for the development of value-added foods with health-promoting properties. Nopal provides fiber

dietetics, phenolic compounds, antioxidants, and minerals associated with gastrointestinal and metabolic health benefits [6], [7]. Furthermore, recent research indicates that the bioactive compounds present in Opuntia ficus-indica possess antioxidant and prebiotic potential, promoting the development of functional products aimed at consumers interested in healthy foods [8], [9], [17]. However, the presence of mucilage can alter sensory attributes related to moisture, viscosity, and mouthfeel. In this regard, the appropriate combination of nopal and grains helped mitigate potential negative effects associated with mucilage, resulting in a more balanced texture that is acceptable to consumers.

The results obtained are consistent with previous research on functional energy bars, where the balance between fiber-rich ingredients and components that provide lightness and crunch represents a key factor in consumer acceptance [5], [11]. Similarly, studies on functional foods indicate that, although consumers value products with nutritional benefits, the purchase decision depends largely on pleasant organoleptic attributes, particularly flavor and texture [2], [12], [18]. Therefore, the development of functional foods requires not only increasing nutritional value but also optimizing sensory properties to ensure commercial acceptance.

In recent years, various studies have indicated that physically active consumers show a greater preference for food products that, in addition to providing immediate energy, contribute to overall well-being and the maintenance of healthy eating habits. In this regard, functional energy bars have gained prominence in the food market due to their convenience, portability, and suitability for consumption during sports activities or long workdays [2], [3]. Furthermore, the current trend toward consuming natural and minimally processed products has fostered the development of formulations made with plant-based ingredients and bioactive compounds.

Similarly, the incorporation of functional ingredients into snack-type products represents an important strategy for increasing the added value of processed foods. Recent research indicates that consumers view products that combine nutritional properties with pleasant sensory characteristics favorably, particularly when they contain dietary fiber, antioxidants, and naturally occurring compounds [1], [5]. In this context, the use of nopal in energy bars not only contributes to improving the product's functional profile but also promotes the sustainable use of regional raw materials that are widely available in Mexico.

From a technological standpoint, the appropriate proportion of grains plays an important role in the physical stability and texture of the final product. Puffed rice promotes a light structure and greater crunchiness, while oats provide cohesiveness and moisture retention. However, excessive amounts of soluble fiber can lead to negative changes in attributes related to hardness and mouthfeel [10], [11]. Therefore, the balance observed in Treatment 2 may have promoted a more appropriate interaction among the ingredients used, resulting in a more uniform texture that is acceptable to consumers.

Likewise, the development of functional foods made with plant-based ingredients represents a significant alternative for innovation in the food industry. Currently, there is a

growing interest in products aimed at consumers seeking healthy alternatives with a lower degree of processing and a higher content of functional compounds [19]. In this regard, the formulation developed in this study may serve as a basis for future research on functional foods targeted at the sports sector and consumers interested in natural products with additional beneficial properties.

Furthermore, the findings of this study demonstrate that the use of regional raw materials such as nopal can contribute to the development of innovative products with functional potential and added value. The use of traditional ingredients in modern formulations supports the sustainable use of local agri-food resources and promotes the diversification of healthy foods [1], [19]. In this context, incorporating nopal into energy bars represents a viable strategy for designing products aimed at physically active consumers and individuals interested in natural foods.

Finally, the results suggest that the formulation corresponding to Treatment 2 presented the best balance between nutritional value, texture, and sensory acceptance; therefore, it could be considered a promising alternative for the development of functional energy bars with potential for industrialization and commercialization. However, due to the small sample size and the use of convenience sampling, the results should be interpreted with caution. Therefore, it is recommended that further research be conducted on nutritional analysis, antioxidant capacity, physicochemical stability, shelf life, and acceptance among different population groups, with the aim of strengthening the product's technological and commercial potential.

The growth of the global functional foods market has driven the development of products targeted at physically active consumers and individuals interested in natural food alternatives with high nutritional value. In this context, functional energy bars represent a segment with significant growth potential due to their convenience, ease of consumption, and the ability to incorporate bioactive ingredients [1], [19].

From a technological standpoint, incorporating nopal into snack-type products may represent a viable strategy for diversifying the agroindustrial use of this cactus, especially in arid and semi-arid regions where it is a widely available plant resource [6], [7].

Currently, consumers are showing greater interest in foods made with natural, minimally processed ingredients that offer additional functional benefits, which increases the commercial potential of innovative products made with regional raw materials [2], [19].

CONCLUSIONS

Sensory evaluation identified the formulation with the highest acceptance among potential consumers of the energy bar made with nopal and grains, demonstrating the importance of properly balancing the functional ingredients and the product's organoleptic properties. The results showed that the sensory characteristics—particularly texture, flavor, and overall acceptability—were directly

influenced by the proportion of puffed rice and rolled oats used in the evaluated formulations.

The formulation consisting of 70% puffed rice, 25% rolled oats, 3% toasted walnuts, and 2% raisins showed the highest level of sensory acceptance, receiving ratings corresponding to the categories “I like it very much” and “I like it a lot.” This combination resulted in an energy bar with a balanced texture, adequate crunch, and pleasant flavor —attributes that contributed to consumer preference during the verbal hedonic test.

Furthermore, the results show that incorporating nopal and grains into energy bar-type products represents a viable alternative for the development of functional foods aimed at physically active consumers and people interested in natural products with additional nutritional benefits. Nopal provided functional value due to its dietary fiber and antioxidant compounds, while the cereals contributed to the energy content and improved the product’s technological and sensory properties.

The research also confirmed that the use of regional, plant-based raw materials can contribute to the development of innovative products with the potential for commercial acceptance. In this regard, the use of nopal as a functional ingredient represents a sustainable strategy that fosters the diversification of value-added foods and promotes the use of agri-food resources available in arid and semi-arid regions of Mexico.

Similarly, the results suggest that striking a balance between fiber-rich ingredients and components that provide lightness and crunch is essential to avoid negative effects on the texture and acceptability of the final product. Therefore, the selected formulation can be considered a promising alternative for the development of functional energy bars with competitive sensory characteristics within the health food market.

Future Research Directions

As a first line of future research, we propose conducting studies aimed at the comprehensive characterization of the energy bar, including analysis of its nutritional composition, antioxidant capacity, physicochemical properties, storage stability, shelf life, and microbiological quality. These studies will generate scientific evidence to support its functional benefits and facilitate its industrial scaling.

As a second future line of research, it is recommended to evaluate the product’s acceptance among different population groups, as well as to develop new formulations by incorporating other plant-based functional ingredients. Additionally, it will be beneficial to analyze its technical, economic, and commercial viability to strengthen its innovation potential and market positioning within the functional foods market.

DATA AVAILABILITY STATEMENT

Study data:	The data supporting the findings of this study are available upon reasonable request to the corresponding author.

Protocol / Code / Questionnaire:	Not publicly available.
Funding Source:	This research did not receive external funding.
Conflict of Interest:	The authors declare that there is no conflict of interest related to this manuscript.
Ethical approval:	Not applicable.

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AUTHOR CONTRIBUTIONS (CRediT Taxonomy)

Role	Author(s)
Conceptualization	Nancy Patricia Meade Almazán Bertha Yadira Elizondo Nolazco Claudia Cárdenas Vega
Methodology	Nancy Patricia Meade Almazán Bertha Yadira Elizondo Nolazco Claudia Cárdenas Vega
Validation	Nancy Patricia Meade Almazán Bertha Yadira Elizondo Nolazco

	Claudia Cárdenas Vega Susana del Carmen Torres Morales
Formal Analysis	Nancy Patricia Meade Almazán Bertha Yadira Elizondo Nolazco Claudia Cárdenas Vega Susana del Carmen Torres Morales Patricia Aidé Fernández García
Research	Nancy Patricia Meade Almazán Bertha Yadira Elizondo Nolazco Claudia Cárdenas Vega Susana del Carmen Torres Morales Patricia Aidé Fernández García
Resources	Nancy Patricia Meade Almazán Bertha Yadira Elizondo Nolazco
Data Curation	Nancy Patricia Meade Almazán Claudia Cárdenas Vega
Writing – Original Draft	Nancy Patricia Meade Almazán Bertha Yadira Elizondo Nolazco
Writing – Review and Editing	Nancy Patricia Meade Almazán Bertha Yadira Elizondo Nolazco Claudia Cárdenas Vega Susana del Carmen Torres Morales Patricia Aidé Fernández García
View	Nancy Patricia Meade Almazán Claudia Cárdenas Vega
Supervision	Nancy Patricia Meade Almazán Bertha Yadira Elizondo Nolazco
Project Management	Nancy Patricia Meade Almazán

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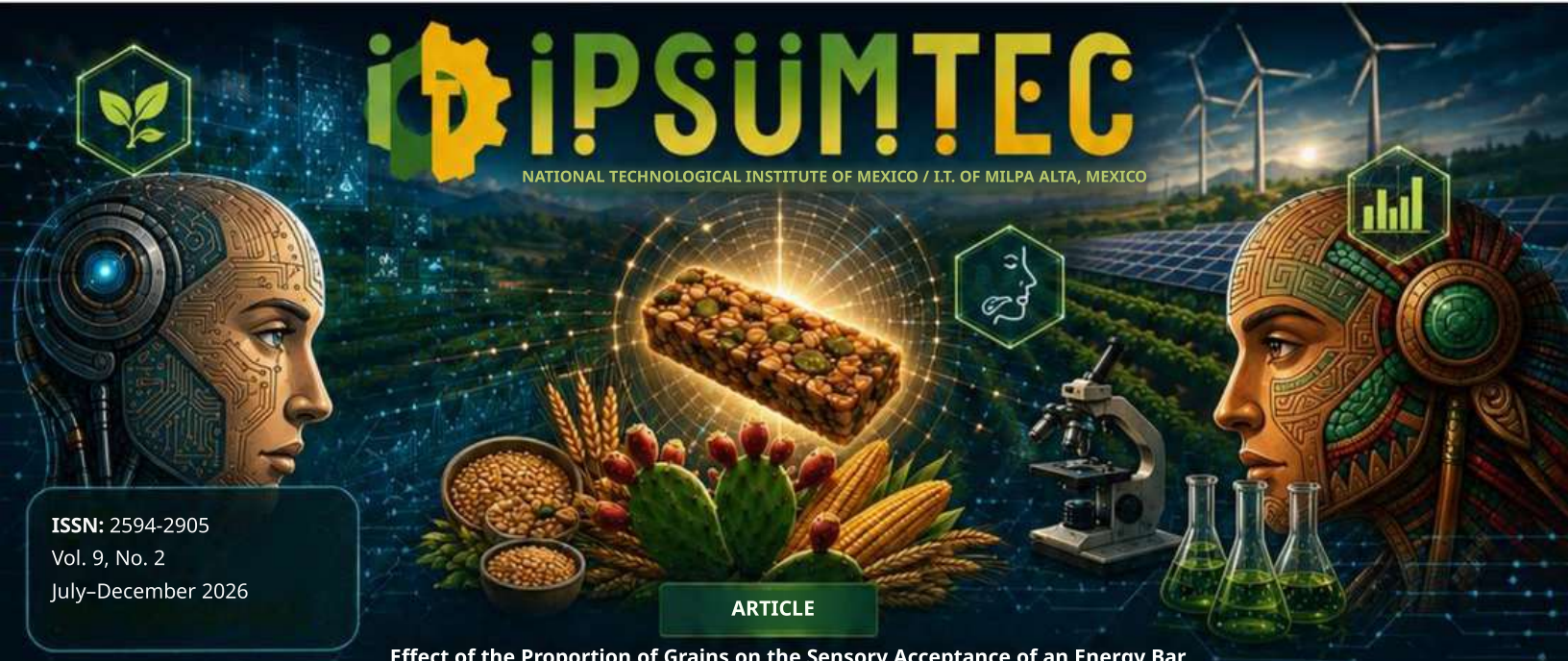
ISSN: 2594-2905
Vol. 9, No. 2
July–December 2026



ARTICLE

Effect of the Proportion of Grains on the Sensory Acceptance of an Energy Bar Containing Nopal

https://doi.org/10.61117/ipsumtec.v8i2.465

AUTHOR



Nancy Patricia Meade Almazán

PROFILE

Master's degree in Education with a specialization in Mathematics and a Bachelor's degree in Computer Science, affiliated with the National Technological Institute of Mexico, Linares Technological Institute. She has 31 years of academic experience and is involved in teaching, research, and academic administration. Her research focuses on food innovation, sustainability, and the use of regional resources, with expertise in the development and evaluation of food products.

BIOGRAPHY

Holds a Master's Degree in Education with a specialization in Mathematics and a Bachelor's Degree in Computer Science from the National Technological Institute of Mexico, Linares Institute of Technology. She has 31 years of academic experience and participates in teaching, research, and academic management activities. Her research interests focus on food innovation, sustainability, and the utilization of regional resources, with experience in the development and sensory evaluation of food products.

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EMAIL
nmeade@linares.tecnm.mx

AFFILIATION
National Technological Institute of Mexico
Linares Institute of Technology

EXPERIENCE
31 years

RESEARCH AREAS
- Food Innovation
- Sustainability
- Utilization of regional resources
- Sensory evaluation of food products

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AUTHOR

Bertha Yadira Elizondo Nolazco



PROFILE

Master's degree in Business Administration with a specialization in Quality and Productivity. Professor and researcher at the National Technological Institute of Mexico, Linares Institute of Technology. Her work focuses on food quality and safety, innovation, and the sustainable use of agri-food resources. She is a member of the National Network for Monitoring and Data Collection and actively participates in research projects and academic and scientific activities.

BIOGRAPHY

Master of Business Administration with a specialization in Quality and Productivity. Professor and researcher at the National Technological Institute of Mexico, Linares Institute of Technology. Her work focuses on food quality and safety, innovation, and the sustainable use of agri-food resources. She is a member of the National Network for Monitoring and Data Collection and actively participates in research projects and academic and scientific activities.

TEACHING · RESEARCH · ACADEMIC MANAGEMENT · FOOD INNOVATION

EMAIL

byelizondo@linares.tecnm.mx

AFFILIATION

National Technological Institute of Mexico
Linares Institute of Technology

EXPERIENCE

Professor and researcher with experience in quality, food safety, and agri-food innovation.

RESEARCH AREAS

- Food Quality and Safety
- Sustainable use of agri-food resources
- Innovation in food products
- Monitoring and data collection

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AUTHOR



ME. Claudia Cárdenas Vega

PROFILE

Master of Education: Teacher Training Program from the National Pedagogical University (2016); Full-time Research Professor at the Academies of Engineering in Business Management, and the Academy of Systems and Computing at TecNM Linares Campus, Nuevo León; Faculty Member with "Desirable Profile 2025" Recognition; Academic Body Leader in Applied Research on Resource Utilization 2026; Member of the National Network for Monitoring and Data Collection. ORCID 0000-0002-3649-4896.

BIOGRAPHY

Holds a Master's degree in Education (specializing in Teacher Training) from the National Pedagogical University (2016); full-time faculty researcher in the Business Management Engineering and Systems and Computing departments at TecNM Campus Linares, Nuevo León; holds the "Desirable Profile" recognition (valid through 2025); leader of the "Applied Research on Resource Utilization" academic group (valid through 2026); and member of the National Monitoring and Data Collection Network.
ORCID 0000-0002-3649-4896.

TEACHING · RESEARCH · ACADEMIC MANAGEMENT · FOOD INNOVATION

EMAIL
claudia.cv@linares.tecnm.mx

AFFILIATION
TecNM Linares Campus, Nuevo León

EXPERIENCE
Full-time Faculty Researcher with academic leadership in applied research and teacher training.

RESEARCH AREAS
- Teacher Training
- Business Management
- Systems and Computing
- Resource Utilization
- Monitoring and Data Collection

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AUTHOR



MAE. Susana del Carmen Torres Morales

PROFILE

Master of Business Administration with a specialization in Finance from Tec Milenio University (2015); Research Professor at the Academy of Engineering and Business Management at TecNM's Linares campus in Nuevo León, recognized for her outstanding participation in multidisciplinary scientific projects related to food technology, sustainability, technological innovation, and occupational health. Member of the Academic Corps for Applied Research on Resource Utilization 2026, and member of the National Network for Monitoring and Data Collection.

BIOGRAPHY

Holds a Master of Business Administration (MBA) with a specialization in Finance from Universidad Tec Milenio (2015); serves as a Research Professor in the Department of Engineering and Business Management at TecNM (Linares, Nuevo León campus); recognized for outstanding participation in multidisciplinary scientific projects involving food technology, sustainability, technological innovation, and occupational health. Member of the "Applied Research on Resource Utilization 2026" Academic Research Group and the National Network for Monitoring and Data Collection.

TEACHING · RESEARCH · ADMINISTRATION ACADEMIC · INNOVATION IN FOOD TECHNOLOGY

EMAIL
susana.torres@linares.tecnm.mx

AFFILIATION
TecNM Linares Campus,
Nuevo León

EXPERIENCE
Faculty researcher with leadership experience in multidisciplinary projects in food technology, sustainability, and innovation.

RESEARCH AREAS
- Food Technology
- Sustainability
- Technological innovation
- Occupational health
- Business Management

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AUTHOR



Patricia Aidé Fernández García**, M. A.**

PROFILE

With a bachelor's degree in Computer Science and a master's degree in Education, she has professional experience in both academic and technological fields. She has served as an instructor in engineering programs. Her career combines expertise in computer science, education, and professional training at the higher education level. She has participated in academic and administrative activities at the Linares Institute of Technology.

BIOGRAPHY

With a Bachelor's Degree in Computer Science and a Master's Degree in Education, she has professional experience in the academic and technological fields. She has worked as a professor in various engineering programs. Her professional background combines knowledge of computer science, education, and higher education training. She has participated in academic and administrative activities at the Instituto Tecnológico de Linares.

TEACHING · TECHNOLOGY · ACADEMIC MANAGEMENT · HIGHER EDUCATION

EMAIL
patricia.fernandez@linares.tecnm.mx

SUBSCRIPTION
Linares Institute of Technology

EXPERIENCE
Instructor in Engineering Programs

RESEARCH AREAS

- Computer Science
- Education
- Vocational Training
- Academic administration
- Administrative Activities

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