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Original Research Article

Impact of Hempseed Incorporation on the Quality Characteristics of Granola: Nutritional and Sensory Evaluation

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Abstract: *Health-conscious consumers are increasingly seeking functional foods enriched with natural ingredients to promote wellness. Hemp seeds, a nutrient-dense byproduct of commercial fiber production, offer potential for incorporation into food products to enhance both nutritional and sensory attributes.* ***Objective:*** *This study aimed to develop hempseed-incorporated granola using two different processing techniques and to evaluate its nutritional composition, functional properties, and sensory acceptability.* ***Methods:*** *A comparative experimental study was conducted to prepare hempseed-based granola using oven-baked and roasted methods. Proximate composition (moisture, ash, fat, fiber, protein, carbohydrate), functional properties (bulk density, oil-holding capacity, water-holding capacity, swelling index), and sensory evaluation (taste, color, aroma, texture, mouthfeel, overall acceptability) were assessed. Data were analyzed using standard statistical procedures to determine significant differences between treatments (p<0.05).* ***Results:*** *The oven-baked granola demonstrated significantly higher ash (2.68%), fat (22.47%), fiber (5.52%), and protein (16.45%) contents, whereas roasted granola contained higher moisture (4.30%) and carbohydrate (56.17%) levels. Functional characteristics were improved in the oven-baked product, including bulk density (1.00), oil-holding capacity (2.85), water-holding capacity (2.19), and swelling index (3.60). Sensory scores indicated superior consumer acceptance for the oven-baked granola in terms of taste, color, aroma, texture, mouthfeel, and overall acceptability compared with roasted granola.* ***Conclusion:*** *Incorporating hempseed enhances the nutritional, functional, and sensory qualities of granola, particularly when processed using oven-baking methods. This product provides a sustainable and health-promoting snack alternative for individuals pursuing nutritious and natural dietary options.*

Keywords: Functional Food, Hempseeds, Granola, Health-Conscious Individuals, Breakfast Snack

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Introduction

Diet plays a crucial role in maintaining health and preventing disease. In developing countries like Pakistan, food insecurity and malnutrition persist as significant challenges. According to the World Food Programme (WFP) (1), Pakistan ranks 99th on the Global Hunger Index, with nearly 40% of children aged 6–59 months experiencing chronic malnutrition. A nutrient-rich diet that includes functional ingredients can help reduce malnutrition and the risk of non-communicable diseases, such as diabetes, cardiovascular disease, and certain types of cancer. Functional bioactive compounds—including antioxidants, fiber, and probiotics—offer health benefits beyond basic nutrition by reducing oxidative stress, improving digestion, regulating blood sugar, and supporting immune function (2).

The growing global demand for plant-based diets has drawn attention to nutrient-dense foods, including fruits, vegetables, seeds, and legumes. These plant-derived ingredients are rich in vitamins, minerals, flavonoids, and anthocyanins that help manage chronic disease symptoms (3). Among them, hemp seeds have emerged as a promising superfood due to their nutritional profile and environmental sustainability (4).

Hemp (Cannabis sativa L.) has been cultivated for over 10,000 years, initially in Central Asia and now widely in Pakistan, China, and Iran (5). While historically used for textiles and ropes, its seeds are increasingly valued as a functional food (6). The global industrial hemp market is projected to grow at an annual rate of 22.4% from 2024 to 2029 (7). Hemp seeds are small, oval, and nutrient-rich, containing 30% protein, 30% oil, and 25% carbohydrates. Shaw et al. reported that whole seeds provide 24.8% protein, 27.6% crude fiber, and 35.5% oil, while hemp flour can reach 40.7% protein and 30.5% fiber (8,9). Their omega-3 fatty acids improve cardiovascular function and lower cholesterol levels, while gamma-linolenic acid supports skin health and regulates blood pressure. Vitamins D and E enhance immunity and reduce inflammation (10). Hemp fiber, primarily in the pericarp, has an insoluble-to-soluble ratio of 80:20, aiding digestion. Hemp seed oil is equally valuable, containing provitamin A, vitamin E, minerals (Mg, Ca, K), and polyunsaturated fatty acids that support metabolic health. Bioactives, such as tocopherols and sterols, provide antioxidant and anti-inflammatory effects, thereby reducing cardiovascular risks (11).

Among functional foods, granola has gained worldwide popularity as a convenient, nutrient-dense snack. In Pakistan, consumption of baked cereals and breakfast products is rising, with an annual growth rate of 7.3% (12). Traditional granola consists of oats, hemp seeds, pumpkin seeds, sunflower seeds, almonds, coconut, and honey, baked until crisp and crunchy. Its moderate glycemic index helps regulate postprandial glucose and insulin (13). Oats, the main component, provide beta-glucan—a soluble fiber known to lower LDL cholesterol and support heart health (14). Increasingly, granola is consumed not only at breakfast but also as a functional snack that enhances energy, satiety, and overall wellness (15).

Despite this trend, many available snacks remain low in protein, fiber, and essential nutrients, and some even generate harmful compounds during processing (16). Developing plant-based functional snacks, such as hemp seed granola, is therefore crucial in addressing nutritional gaps. Enriching granola with hemp seeds enhances its protein, fiber, and omega-3 content, while also offering a better taste and variety. With rising consumer demand for clean-label, nutrient-dense foods, hemp seed granola represents a sustainable and marketable product that supports long-term health (17).

Methodology

Procurement of Raw Material

The raw materials used for granola preparation were selected based on their richness, quality, and nutritional value. The ingredients were sourced from trusted local suppliers in Lahore, Pakistan. A grocery shop was used to obtain rolled oats, which were free of additives and preservatives. A local organic store was used to purchase almonds, hemp seeds, sunflower seeds, pumpkin seeds, honey, coconut oil, and raisins.

Granola was prepared using the method described by Soni *et al*. (2020), with slight modifications. Two processing techniques were applied: oven-baking and the roasted frying method.

For the oven-baked granola, dry ingredients, including rolled oats, hemp seeds, sunflower seeds, pumpkin seeds, chopped almonds, coconut, turmeric, cinnamon, and a pinch of salt, were combined in a large bowl to ensure even mixing of the spices and salt. In a separate bowl, melted coconut oil and honey were mixed and then added to the dry mixture. The ingredients were stirred thoroughly until fully coated, then evenly spread onto a baking tray and baked at 150°C for 5 minutes. After baking, the granola was allowed to cool, and raisins were added.

In the roasted treated granola, all ingredients were weighed precisely. A non-stick pan was preheated over medium to low flame, and coconut oil was melted. Sunflower seeds, pumpkin seeds, hemp seeds, and chopped almonds were roasted for 3–4 minutes, followed by the addition of rolled oats and shredded coconut, which were roasted for another 5–6 minutes until golden and aromatic. Turmeric, cinnamon, and salt were sprinkled in and mixed evenly. Honey was then added and stirred for 2–3 minutes, until the mixture became sticky and started to clump. The mixture was cooled on a clean surface, and the raisins were then incorporated.

Table 1. Treatment plan for granola production

Treatment	Rolled Oats (g)	Hemp Seeds (g)	Sunflower Seeds (g)	Pumpkin Seeds (g)	Chopped Almonds (g)	Coconut (g)	Honey (mL)	Coconut Oil (mL)	Turmeric (g)
Roasted treated granola	20	3	4	4	3	3	7	3	0.3
Baked treated granola	30	3	4	4	3	3	7	3	0.3

Proximate Analysis

Proximate analysis, including moisture, protein, fat, fiber, ash, and carbohydrates, was performed on granola samples using the AOAC (2023) methods.

Determination of Moisture

The moisture content was determined using a hot air oven. A 5 g homogenized sample was dried at 105 °C for 4 hours until it reached a consistent weight. After cooling in a desiccator, the moisture content was calculated based on the weight loss.

$$\text{Moisture (\%)} = \frac{\text{Fresh sample weight (g)-Dried sample weight (g)}}{\text{Fresh sample weight}} \times 100$$

Fat Determination

The crude fat was determined by Soxhlet extraction. A 2 g sample was weighed and extracted with n-hexane for 4-6 hours. After drying and chilling, the increase in flask weight was measured as an indicator of fat content. The following formula was used to calculate the crude fat content of the sample.

$$\text{Crude fat (\%)} = \frac{\text{Weight of hexane extract (g)}}{\text{Sample weight (g)}} \times 100$$

Protein Determination

The crude protein of granola was determined using the Kjeldahl method. A 2 g sample was digested in concentrated H_2SO_4 and heated at 250 °C for 4 hours until clear. After cooling, the digest was diluted with 50 mL of distilled water. The solution was gradually alkalinized by adding 50 mL of 40% NaOH. The ammonia released was trapped in boric acid and titrated with 0.1N acid. Nitrogen was calculated and multiplied by 5.80 to determine protein content.

$$\text{Nitrogen (\%)} = \frac{\text{Volume of 0.1N suphuric acid used} \times 0.0014 \times 250}{\text{Sample weight} \times \text{Aliquot volume}} \times 100$$

Crude protein = Nitrogen (%) ×5.80

Ash Determination

To determine the ash content of granola, a 3 g dry sample was ignited in a muffle furnace at 550 °C for 4-5 hours. Before being transferred to the furnace, the initial combustion was carried out on a hot plate. The residue was cooled in a desiccator and weighed to determine the total mineral content. Used this formula to calculate ash content after recording all the weights.

$$\text{Ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100$$

Fiber Determination

To determine the crude fiber content of granola, a 5-g defatted sample was boiled with 1.25% H_2SO_4 and 1.25% NaOH for 30 minutes. The residue was dried and ignited at 550 °C in a muffle furnace. The fiber content was calculated by subtracting the ash weight from the dry weight.

$$\text{Crude fiber (\%)} = \frac{\text{Weight (after drying) - Weight (after ashing)}}{\text{Sample weight (g)}} \times 100$$

Carbohydrate determination

The nitrogen-free extract was used to determine the carbohydrate content of granola. It was calculated by subtracting the sum of the measured levels of moisture, ash, fiber, fat, and protein from the total amount of the sample. Then it uses this formula to calculate the total carbohydrate content.

NFE%= 100- (Crude fat%+ Crude protein%+ Crude fiber%+ Moisture% + Ash %

Functional Analysis

This method was used to determine the functional properties of the granola sample. This included water absorption capacity (WHC), bulk density (BD), oil absorption capacity (OHC), and swelling index (SI).

Bulk Density

A 25 cm³ graduated cylinder was filled with a granola sample, and the volume was recorded. Gently, this cylinder was tapped ten times on the top of the bench to pack it. The decrease in the volume was marked. The bulk density was calculated by dividing the final volume (mL) after tapping by the initial volume (mL).

Bulk Density = Mass / Volume

Water Absorption Capacity

In a centrifuge tube, 1 g of sample was thoroughly mixed with 10 cm³ of distilled water for 30 minutes using a vortex mixer. Thereafter, the solution was left undisturbed for 30 minutes at room temperature and then agitated at 5000 rpm in a centrifuge. After 30 minutes of centrifugation, the supernatant volume was measured. The liquid supernatant was then added to a weighed crucible and heated in a hot air oven set at 105 °C to remove moisture. After drying, the weight of the crucible with the sample was noted. The water absorption capacity was calculated by dividing the weight of the centrifuged tube minus its initial weight by the weight of the sample.

Oil Absorption Capacity

In a centrifuge tube, 0.5 g of granola sample and 0.3 g of soya oil were mixed thoroughly. It was left undisturbed for 30 minutes and then centrifuged for 25 minutes at 5000 rpm. The volume of free oil was measured. The results were reported as oil-bound per 100 g sample.

Swelling Capacity

For the determination of the swelling index (SI), 5 mL of the sample was placed into a volumetric cylinder, and water was added to a total volume of 50mL. It has been shaken and then placed in equilibrium for half an hour. A volume change was noted. The % of swelling index was calculated using the following formula.

$$\text{Swelling index (\%)} = \frac{\text{Volume of water absorbed}}{\text{Volume of sample used}} \times \mathbf{100}$$

Sensory Analysis

The sensory characteristics, including taste, aroma, overall acceptability, appearance, crispiness, and texture of Granola, were examined using the hedonic scale method. A panel of 15 assessors, including postgraduate students and faculty members, was selected to evaluate the granola, where one was used to indicate extreme dislike and 9 to indicate extreme likeness.

Statistical Analysis

All analyses were performed in triplicate, except for sensory analysis. The averages of means and ANOVA tables were calculated using Minitab 18 software. The differences between the treatments were also measured.

Results / Discussion

Proximate analysis

Estimation of Moisture Content

Moisture can be described as the amount of liquid present in a sample. It is important in determining the overall quality of food items since it influences their lifespan, storage stability, and texture. The oven-baked granola in the present study had a moisture content of 4.23%, while the roasted granola had a moisture content of 4.30%. Oven-baked granola was found to have a lower moisture content than roasted granola. This distinction can be attributable to the different cooking methods and moisture retention properties of each approach. Oven baking often results in decreased moisture content because the regulated heat application stimulates water evaporation from the product. According to studies, baked foods frequently contain moisture values of less than ten percent. These results are in line with the findings of Beleya (18), who discovered that the moisture levels of various cereal-based granolas varied between 4.80% and 7.79%. In comparison, the frying method retains more moisture. According to research, frying can result in higher moisture content because water is absorbed throughout the cooking process.

Estimation of protein content

The current study found that the protein content of oven-baked granola and roasted granola was 16.45% and 14.17% on a dry basis, respectively. Oven-baked granola is thus an efficient source of protein. Protein is a critical factor in determining the nutritional value of food products, as it plays a significant role in various bodily functions and overall health. This increase could be related to better protein retention during oven baking, as lower and more consistent heat reduces protein breakdown or denaturation. Hemp seeds have a high protein content (20–25%), including all essential amino acids, thereby providing a complete protein source (19). Our findings are consistent with those published by Coelho and Salas-Mellado (20), who observed higher protein levels in oven-baked goods (21). The reduced protein content of roasted and fried granola could be attributed to higher surface temperatures, which can cause partial denaturation or breakdown of protein structures. Additionally, oil absorption during frying may affect the macronutrient distribution, resulting in a lower protein concentration in the product.

Estimation of ash content

The ash content is the sum of all inorganic components, such as minerals, that remain after a sample has been completely combusted. It measures the mineral content of food goods. The ash content found in this study was 2.68% in oven-baked granola. Our results are within the range provided by Chompoo et al. (22). Roasted and fried granola have a lower moisture content (i.e., 2.12%) compared to oven-baked granola. Lobacz et al. (23) reported that the ash concentration of various oven-baked multigrain granolas ranged from 1.6% to 2.4%, indicating that dry-heat baking methods help retain the natural mineral content of the components. Lower ash values have been seen in fried or extruded snack bars, where intensive thermal processing and oil absorption may contribute to partial degradation or dilution of mineral components (24).

Estimation of fiber content

The crude fiber provides an approximation of the carbohydrates and lignin present in food or plants. It improves the density, texture, and nutrition. It also helps to improve digestive health, lower the glycemic index, and reduce the risk of chronic diseases. Oven-baked granola had 5.52% fiber, which is comparatively higher than the fiber content of roasted frying granola at 4.84 %. The higher fiber stability in oven-baked could be attributed to the mild, consistent heat treatment that avoids fiber component breakdown or leaching during processing. The fiber content in the present study was higher than the range provided by Ahmad et al. (25). Cereal-based or high-temperature extruded bars often show significantly lower fiber values due to heat breakdown of soluble fibers and probable dilution from absorbed oil (26). This variation in results may be due to the use of higher temperatures for a short time, as some fibrous components degrade at higher temperatures, resulting in a lower overall fiber content.

Estimation of fat content

Their fat content significantly influences the texture, mouthfeel, energy density, and shelf life of granola. The current study found that oven-baked granola had a fat content of 22.47%, while roasted frying granola had 18.39 % fat content on a dry basis. These higher fat contents can be attributed to the higher fat content in hempseed, i.e., 23% and 31% (27). The higher fat content of oven-baked granola can be attributed to the greater retention of naturally occurring lipids from chia seeds and other ingredients, with no loss due to oil interactions or heat-induced oxidation. As hempseeds are high in omega-3 fatty acids, when employed in baking, these fats are more effectively preserved under controlled dry-heat conditions. In contrast, during soaked-frying, some fat-soluble molecules may break down or migrate, and oil absorption might cause alterations in the total lipid profile.

Estimation of carbohydrate

Carbohydrate content is a significant nutritional component in granola, affecting energy density and glycemic response. Fried granola, in the present study, had a significantly higher carbohydrate content (56.17%) than oven-baked granola (48.66%). Oven-baked samples have more protein, fat, and fiber, resulting in a lower proportion of carbs per 100g.

Functional analysis

Bulk Density

The bulk density (BD) of a substance is the weight of its particles divided by its total volume. It is a significant physical attribute of a snack, since it reflects the compactness of ingredients and the structural organization. It affects product texture, packaging efficiency, and consumer impression of satiety. In the present research, the bulk density (g/mL) of oven-baked granola was found to be greater than that of roasted frying granola. This suggests that oven baking resulted in a more compact and less porous structure than soaking and frying. Our results showed a higher bulk density content compared to those reported by Taheri-Garavand et al. (28). They described the bulk density of hempseed granola as typically ranging between 0.5 and 0.8 g/mL, with variations attributed to processing methods. Another study on granola goods found bulk density values ranging from 0.12 to 0.27 g/mL, with baked granola typically having higher densities than extruded granola (29).

Water holding capacity (WHC)

Water holding capacity (WHC) is a significant functional attribute in granola, as it affects freshness, shelf life, and texture through its ability to retain moisture. The findings of the current study showed that oven-baked granola had a water holding capacity (WHC) of 2.85 g/g. In contrast, roasted granola had a water holding capacity (WHC) of 2.42 g/g. The higher WHC in oven-baked samples may be attributed to better preservation of dietary fiber and protein structure, especially from chia and hemp seeds. Similar findings have been reported in experiments where heat treatments improved the water retention qualities of high-fiber foods. Awoyale et al. (30) reported that baked granola had increased

WHC due to intact mucilage and decreased fat migration. In contrast, frying can damage soluble fiber and promote surface hardness, lowering water absorption capacity.

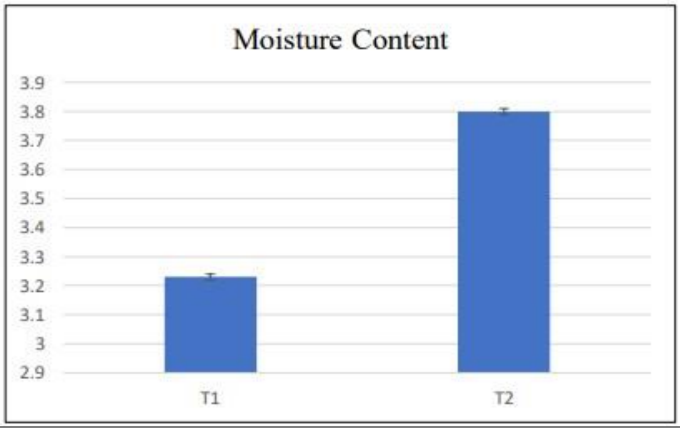

Figure *1*. Graph for the moisture % of Granola
(T_1: Oven baked granola, T_2: Roasted frying granola)

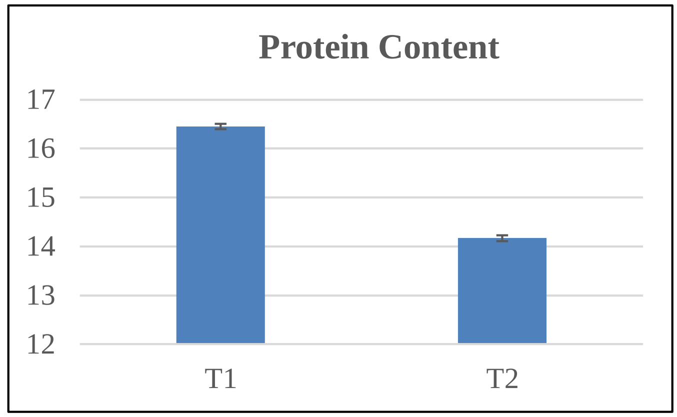

Figure *2*. Graph for protein % of Granola

(T_1: Oven baked granola, T_2: Roasted frying granola)

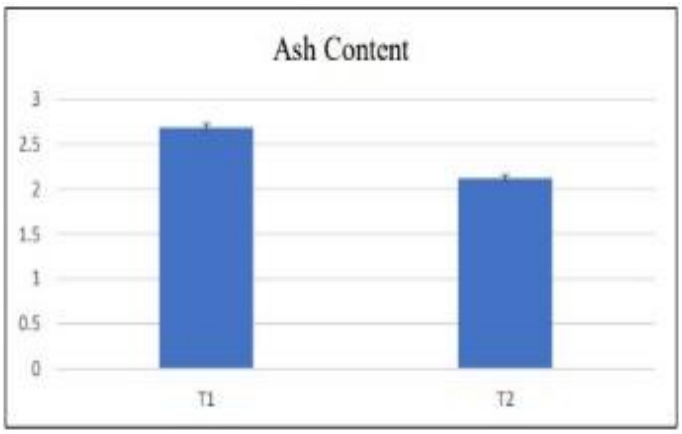

Figure 3. Graph for ash% % of Granola
(T_1: Oven baked granola, T_2: Roasted frying granola)

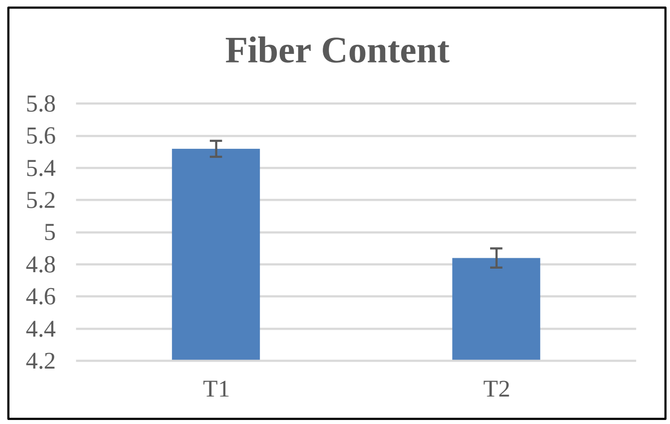

Figure 4. Graph for fiber % of Granola
(T_1: Oven baked granola, T_2: Roasted frying granola)

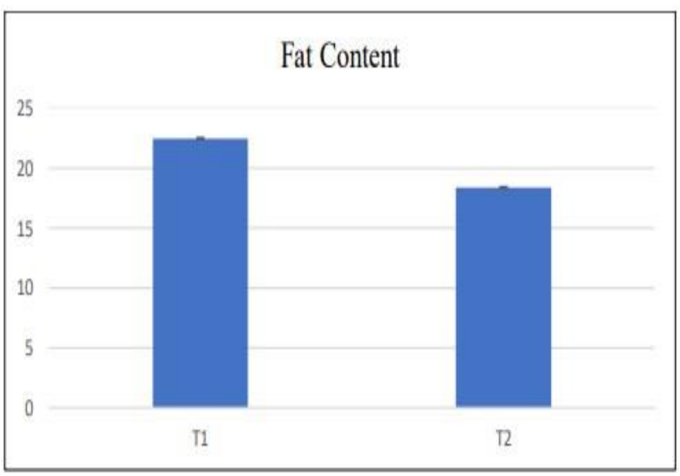

Figure 5. Graph for fat % of Granola (T_1: Oven baked granola, T_2: Roasted frying granola)

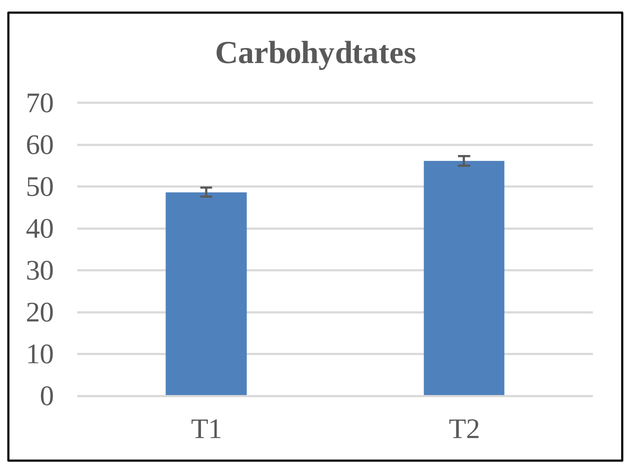

Figure 6. Graph for carbohydrates % of Granola (T_1: Oven baked granola, T_2: Roasted frying granola

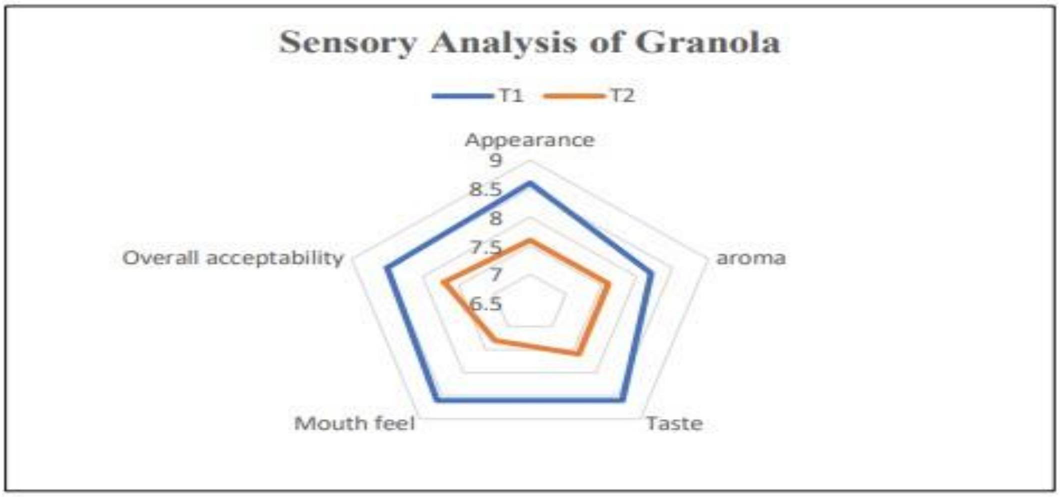

Figure 7 Sensory Analysis of Granola

Conclusion

This research demonstrates that developing a healthy and acceptable snack using natural, plant-based ingredients can support both sustainability in food systems and personal health goals. Among the treatments, the oven-baked granola showed slightly better sensory acceptance and nutritional stability during storage. The infusion of hemp seeds contributed valuable fiber, protein, and antioxidants, making the product suitable for health-conscious consumers. Functional snacks, such as granola, can offer natural nutrients in a convenient form and help support better dietary habits. This study highlights the importance of straightforward ingredient combinations and processing methods in creating clean-label products that align with current health and wellness trends. These findings encourage further exploration of similar snack innovations, shelf-life improvements, and the development of consumer-focused functional foods.

Declarations

Data Availability statement
All data generated or analysed during the study are included in the manuscript.
Ethics approval and consent to participate
Approved by the department concerned. (IRBEC-24)
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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

AW
Writing – Original Draft, Study Design
AM
Conception of Study, and Supervision
IS
manuscript review, Data analysis
IF
Review of Literature, Data entry
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All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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