DEVELOPMENT AND QUALITY EVALUATION OF MULTI OILSEED HIGH FIBER ENERGY BAR

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Abstract

The growing demand for convenient, nutritious, and functional foods has led to the development of energy bars formulated with diverse plant-based ingredients. This review focuses on the development and quality evaluation of multi-oilseed high-fiber energy bars, highlighting their potential as nutrient-dense snacks. Oilseeds such as flaxseed, chia, sunflower, sesame, and pumpkin seeds are rich in healthy fats, proteins, dietary fiber, and bioactive compounds, contributing to improved nutritional value and functional properties. The formulation strategies, processing techniques, and the role of natural binders and sweeteners in enhancing texture and shelf stability are discussed.

Quality evaluation parameters, including physicochemical properties (moisture content, water activity, texture profile), sensory characteristics, nutritional composition, and storage stability, are critically reviewed. The inclusion of multiple oilseeds not only boosts the fiber content but also enriches the bar with essential fatty acids and antioxidants, making it a healthier alternative to conventional energy bars. Challenges in achieving desirable texture, extended shelf life, and consumer acceptability are also addressed, along with future opportunities for product innovation and functional food applications.

1.Introduction

In recent years, consumer preferences have shifted towards functional and convenience foods that offer both nutritional benefits and sensory appeal. Energy bars have emerged as a popular ready-to-eat snack due to their portability, balanced energy density, and ability to serve as a quick meal replacement. Traditional energy bars, however, are often criticized for their high sugar content, low fiber levels, and limited functional ingredients. To address these concerns, the incorporation of multiple oilseeds—such as flaxseed, chia, sunflower, sesame, and pumpkin seeds—has gained attention in product development. These oilseeds are excellent sources of plant-based proteins, essential fatty acids (omega-3 and omega-6), dietary fiber, and bioactive compounds with antioxidant and anti-inflammatory properties.

Developing a **multi-oilseed high-fiber energy bar** not only enhances its nutritional profile but also supports digestive health, weight management, and cardiovascular well-being. The formulation process involves careful selection of binders, natural sweeteners, and processing methods to ensure optimal texture, palatability, and shelf stability. Quality evaluation of such bars includes assessing their physicochemical properties, sensory attributes, nutritional composition, and storage behavior. This review aims to provide an in-depth analysis of the development process, nutritional significance, and quality evaluation parameters of multi-oilseed high-fiber energy bars, with a focus on their potential role in the functional food market.

2.1 Material

2.1.1 Raw material

Flaxseed, Chia Seed and Jaggery and other material were procured from the local market.

2.1.2 Chemicals

All the chemicals, organic solvents and acids used were of analytical grade. Chemicals required for processing of raw materials, preparation and analysis of formulated products.

2.1.3 Packaging material

The LDPE and HDPE polyethylene were used for storage study of value added food products like energy bar were purchased from the local market.

2.1.4 Processing and analytical equipment

The machineries and equipment such as Single Beam Spectrophotometer, Hunter Lab ColorFlex, Soxhlet Apparatus, Centrifuge etc required to perform the present investigation.

2.2 Methods

2.2.1 Physical properties of Chia seed and flaxseed

2.2.1.1 Colour

Sample colour was determined by visual observation.

2.2.1.2 Shape of seed

The shape of seed was judged by visual observation

2.2.1.3 Weight of 1000 seeds of chia seeds

In order to determine the W_{1000}, eight sub-samples, each one consisting of 100 seeds, were randomly drawn from the bulk sample and weighed on an electronic balance with 0.001g accuracy and then extrapolating this weight to 1000 seeds (Vilche *et al.*, 2003; Tunde and Akintunde, 2004).

2.2.1.4 True Density

The true density (ρt), defined as the ratio of the mass of the sample of seeds to the solid volume occupied by the sample, was determined using an electronic balance reading to 0.0001 g and a pycnometer (50±0.1 ml) (liquid displacement method) (Mohsenin, 1970). Xylene (density: 0.862±0.001 g cm−3) was used instead of water because it is absorbed by seeds to a lesser extent. Due to the short duration of the experiment, xylene absorption was found to be negligible and therefore seeds were not coated for its absorption prevention (Giner and Calvelo, 1987).

2.2.1.5 Angle of repose

The angle of repose (θ) was determined by using a plywood box (0.3m of length, width and height), which had a removable front panel. The box was filled with seeds and the front panel was quickly removed, allowing the seeds to flow to their natural slope. The angle of repose was calculated from the measurements of the horizontal displacement distance of the seeds and the height of the heap (Dutta *et al.*, 1988).

2.2.2 Proximate composition of chia seeds and flaxseed

2.2.2.1 Moisture

It was worked out by weighing 5g sample accurately and subjecting to oven drying at 110ºC for 4-6hrs. Oven dried samples were cooled in desiccators and weighed. The drying was repeated until the constant weights were obtained. The resultant loss in weight was calculated as per cent moisture content. (A.O.A.C., 1990).

2.2.2.2 Crude Fat

Sample (5g) was weighed accurately in thimble and defatted with n-hexane (boiling point 68-72^{0}C) in soxhlet apparatus for 8hrs. The resultant extract was evaporated and crude fat content was calculated as per A.O.A.C. 1990 method.

2.2.2.3 Crude protein

Protein was estimated by Microkjaldhel method using 0.5g of moisture free defatted sample by digestion with concentrated sulphuric acid and digestion mixture at 130-140˚C. Then it was distilled with 40 per cent sodium hydroxide and liberated ammonia was trapped in 4 per cent boric acid, using mixed indicator (methyl red : Bromoceresol green 1: 5). It was then titrated with 0.1N hydrochloric acid, the per cent nitrogen was estimated. Protein content was calculated by multiplying per cent nitrogen by a factor of 6.25 (A.O.A.C., 1990).

2.2.2.4 Total ash

Total ash was determined according to A.O.A.C. (1990). Sample (5g) was weighed into a crucible and burnt completely at low flame till all the material became smokeless. Then it was kept in muffle furnace for 6 hrs at 600ºC then cooled in desiccators and weighed. The sample was again put in muffle furnace till two consecutive weights were constant and per cent ash was calculated.

2.2.2.5 Total carbohydrate

Total carbohydrate was determined by standard procedure using phenol and sulphuric acid. Sample (500 mg) was taken in test tube in an ice bath; 2 ml of 72 per cent H_2SO_4 was added to avoid the burning of sample. Then the volume of solution was made to 23 ml with distilled water. The sample was refluxed in water bath at 90 $\pm$ 5ºC for 3 hr. It was then filtered through a Whatman No. 1 filter paper and volume of the filtrate was made to 50 ml with distilled water. 1ml aliquot was taken for analysis; to this 2ml H_2SO_4 and 0.5ml phenol were added. The standard curve was prepared from serial dilution of standard glucose solution corresponding to 0.2, 0.4, 0.6, 0.8 and 1 µg of glucose. The intensity of colour was measured at 480 nm by spectrophotometers. From the standard curve, the concentration of total sugar was calculated.

2.2.3 Mineral content of Chia seed and flaxseed

Mineral content viz. calcium, iron, zinc mangamese, etc, of chia seeds and flaxseedwere measured by the standard methods (Ranganna, 1985).

2.2.3.1 Estimation of manganese, copper and zinc

Atomic Absorption Spectrophotometer (AAS).

3. Result and Discussion

3.1 Physical properties of flaxseed and chia seed

Properties	Flaxseed	Chia seed
Shape	Flat oval	Oval elliptical
Length (mm)	5.25	1.85
Width (mm)	2.15	1.2
Thickness (mm)	0.8	0.9
Wt. of 1000 seed (g)	6.85	1.5
True density kg/m3	1248.25	1160
Angle of repose (degree)	24.55	29

The physical characteristics of flaxseed and chia seed differ considerably, influencing their behaviour in processing, storage, and functional applications. Flaxseeds have an elongated oval appearance, averaging 5.25 mm in length, 2.15 mm in width, and 0.8 mm in thickness. On the other hand, chia seeds are more rounded and compact, measuring 1.85 mm in length, 1.2 mm in width, and 0.9 mm in thickness. The weight of 1000 flaxseeds is considerably greater at 6.85 g compared to just 1.5 g for chia seeds, highlighting the larger dimensions and increased weight of individual flaxseeds. Flaxseed also has a slightly higher true density of 1248.25 kg/m³, whereas chia seed has a density of 1160 kg/m³, potentially affecting their handling, packing, and separation methods. Additionally, the angle of repose, which indicates flow ability, is lower for flaxseed at 24.55° than for chia seed at 29°, suggesting that flaxseeds have better flow properties. These differences are important in the design and optimization of equipment for processing, conveying, and packaging of oilseeds in food and nutraceutical industries.

3.2 Proximate composition of flaxseed and chia seed

Proximate composition of flaxseed and chia seed (g/100g)

Nutrients	Flaxseed	Chia seed
Moisture	6.00	4.00
Carbohydrates	2.00	7.00

Protein	19.25	16.54
Fat	39.48	30.47
Ash	3.80	4.10
Fibre	28.50	37.70

Chemical composition commonly represents the nutritional value of product. The quality of final product is totally dependent on a quality of raw materials.

From the table-5 it was reported that moisture content 6.0 per cent whereas crude fat content was recorded 39.48 per cent. The proximate composition particularly with respect to crude protein and ash content was reported to be 19.25 per cent and 3.80 per cent respectively. The average value of carbohydrates and fibre of flaxseed was found to be 2.0 and 28.50 per cent respectively. The flaxseed contains good proportions of dietary fibre. Dietary fibre does not engage in food digestion, but by giving bulk weight to food, it helps in digestion.

The chemical parameters of the chia seeds were evaluated. The moisture, total fat, carbohydrates, total protein, total ash, and fibre were 4.0, 30.47, 7.00, 16.54, 4.10 and 37.70 per cent respectively. It fulfil the daily requirements of the adult dietary fiber intake, i.e.,25–35 g/day. The fiber content of chia seeds is also higher than quinoa (7.0 g/100 g), flaxseed (27.3 g/100 g), and amaranth (6.7 g/100 g) (Muñoz et al., 2013).

The Protein content, higher than the other cereals such as wheat, oats, barley, corn, rice, quinoa, and amaranth. Also, due to the absence of gluten in chia seeds, it is recommended for celiac disease patients.

3.3 Mineral composition of flaxseed and chia seed

Mineral composition of flaxseed and chia seed (mg/100g)

Mineral	Flaxseed	Chia seed
Mg	320	270
Zn	3.1	3.5
Ca	188	490
Fe	4.8	6.2

The minerals particularly magnesium and calcium were abundant in both the seeds. Flaxseed had 320 mg whereas chia seed reported 270 mg of magnesium. Moreover, calcium and iron were 188 and 490 and 4.8 and 6.2 mg respectively in flaxseed and chia seed. It can be said that flaxseed and chia seed are good sources of calcium and iron for maintain the health of bones. Chia seed contributes a higher amount of nutrients, i.e., calcium (6 times) than 100 g of milk, and more nutrients, including calcium (13–35 times) than 100 g of wheat, oats, corn, and rice. The results are in agreement with (Kulczyński et al., 2019). Also, chia seeds have 1.8, 6.0, and 2.4 times more iron than lentils, spinach (Muñoz et al., 2013). Iron is the most significant mineral that is involved in the body's blood processing and is the largest component of haemoglobin. Also, flaxseed and chia seed contained 3.1 and 3.5 mg of zinc respectively.

3.4 Effect of roasting treatment on nutritional and anti-nutritional composition of raw materials:

Proximate composition of roasted flaxseed(g/100g)

Nutrients	**Flaxseed**	**Chia seed**
Moisture	2.54	2.21
Carbohydrates	3.25	9.00
Protein	19.80	17.54
Fat	33.48	29.47
Ash	2.80	3.10
Fibre	21.50	33.70

The moisture content in roasted flaxseed is noted at 2.54%, while for roasted chia seeds it is slightly lower at 2.21%. Both values demonstrate significant reduction in moisture content which improves fungicidal obsolescence with respect to shelf-life and microbial inhibition. After roasting, the carbohydrate content in chia seeds is at 9% while for flaxseeds it is just 3.25%. This implies that chia seeds provide more energetic carbohydrates after the roasting process.

Flaxseed does appear to have a higher level of protein at 19.80% when compared to roasted chia seed which has 17.54%. This does mean that flaxseed will remain a more predominant source of plant protein even after cooking. Both types of seeds have very high levels of fat, 33.48% for roasted flaxseed and 29.47% for roasted chia seed. This would indicate that both are sources of essential fatty acids, though flaxseed has a slight advantage.

Chia seeds have a slightly higher ash content (3.10%) than flaxseeds (2.80%), which indicates the presence of minerals and suggests a richer mineral profile. Notably, chia seeds are superior to flaxseeds in terms of dietary fibre content (33.70%), which improves satiety and digestive health. Both seeds are very nutrient-dense overall, but flaxseed has more protein and fat and chia has more fibre and carbohydrates.

3.5 Comparative study of anti-nutritional factors of non-roasted flaxseed and roasted Flaxseed:

Anti-nutritional factors of flaxseed

Nutrients	Un Roasted flaxseed	Roasted flax seed
Phytic acid content (mg/100g)	89.13	87.79
Tannin content (mg/100g)	514.0	328.0

the phytic acid levels remain relatively stable during roasting. In flaxseed, the initial content is 89.13 mg per 100 grams, which decreases slightly to 87.79 mg per 100 grams after roasting—equating to a modest drop of 1.34 mg, or about 1.5%. The mineral binding is still reduced by the slight phytate decline. The controlled roasting improves sensory qualities (nutty flavor, color) and lowers significant anti-nutritional barriers which is in agreement with (Kaur et al., 2024).

The change in tannin content is much more pronounced. Unroasted flaxseed starts with 514.0 mg of tannins per 100 grams, but this number plummets to 328.0 mg per 100 grams post-roasting. This substantial decline of 186.0 mg, or nearly 36.2%, suggests that high temperatures effectively break down polymerized tannins. By efficiently reducing these compounds, roasting—a thermal processing technique—improves the seeds' nutritional bioavailability and digestibility as reported by (Khan & Saini, 2016).

4. Conclusion

Energy bars made with varying flaxseed-to-chia seed ratios showed minor size and weight differences, with the T2 formulation (20:15) achieving the best sensory acceptance due to balanced color, texture, and flavor. Hardness increased with chia seed content, attributed to its gel-forming fiber. Microbial analysis confirmed safety up to 45 days at room temperature, with only slight microbial growth after 60 days. Nutritionally, the T2 bar provided 65.65% carbohydrates, 11.52% protein, 11.53% fat, and 11.35% fiber, delivering a higher energy value of 412.45 kcal compared to the control. The bar also contained essential minerals like magnesium, calcium, iron, and zinc. Techno-economic evaluation showed the T2 bar can be produced cost-effectively at ₹877 per 5 kg batch, priced affordably per unit, making it a nutritious, stable, and economically viable snack well-suited for the Indian health-conscious market.

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