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EXPLORING THE FUNCTIONAL AND NUTRITIONAL BENEFITS OF BLENDING OF DEFATTED PEANUT FLOUR IN THE PREPARATION OF EXTRUDED PRODUCTS

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ABSTRACT

Extrusion technology has emerged as a versatile method for creating innovative, nutrient-dense food products. This article focuses on the development of various extruded products prepared by blending of defatted peanut flour (DPF), highlighting their combined functional and nutritional benefits. Defatted peanut flour has a high protein content, including important amino acids and offers nutritional value, particularly by improving the protein profile of extruded products. The synergy between different raw materials and DPF in extrusion leads to enhanced physicochemical properties, including better expansion, texture, and nutrient retention. This blend is particularly suitable for creating healthy snacks, protein bars, and gluten-free products. The review explores the influence of extrusion parameters, such as temperature, moisture content, and screw speed, on the texture, sensory qualities and nutritional outcomes of these products. It also discusses how the extrusion process improves digestibility and reduces anti-nutritional factors. This paper provides a comprehensive analysis of the potential applications of blending of DPF in the preparation of extruded products in the food industry, addressing consumer demand for healthier and functional foods. Overall, this review emphasizes the development of new, health-conscious extruded meals with enhanced nutritional profiles through blending of defatted peanut flour.

Key words : Defatted peanut flour, Extrusion parameters, Extruded products, Extrusion technology, Functional foods.

Introduction

Extrusion is recognized as a continuous process for cooking, mixing, and forming food products. This technology is both versatile and cost-effective, making it a preferred choice in the food processing industry. During the extrusion process, raw materials undergo significant chemical and structural changes (Ding *et al.*, 2006). Similar to thermoplastic processing, extrusion cooking is favored for producing food analogues from cereals and legumes (Moscicki and Zuilichem, 2011).

The application of extrusion cooking has increasingly expanded to include the production of various food items and ingredients, such as breakfast cereals, baby foods, flatbreads, snacks, meat and cheese analogues and modified starches (Ding *et al.*, 2004). This method of transforming raw components into ready-to-eat foods using a high-temperature, short-time shear process (Sapariya *et al.*, 2022). Extrusion has gained popularity due to its versatility, cost of processing and high production rate. A very wide variety of products are possible by changing the ingredients, the operating conditions of the extruder and the shape of the dies. Extrusion has lower processing costs and higher productivity than other cooking or forming processes (Fellows, 2000).

The history of extrusion in food processing dates back to the 1930s with the introduction of the "forming extruder," initially used for pasta production. Over the years, advancements in extruder technology have led to the development of various types of extruders capable of producing a wide range of food products (Harper and Clark, 1979).

It has been widely adopted as a popular approach for producing a wide range of food products, from basic enlarged snacks to highly processed meat substitutes. (Sapariya *et al.*, 2022). For instance, extruded snack products have been prepared by blending corn flour with defatted peanut flour using a twin-screw extruder (Davara *et al.*, 2022).

Peanut or groundnut (*Arachis hypogaea*), is a species in the legume or "bean" family. It is the major oilseed crop in India and it plays a major role in bridging the vegetable oil deficit in the country. Peanuts in India are available throughout the year due to a two-crop cycle harvested in March and October. Groundnuts are important protein crops in India grown mostly under rain-fed conditions. They have a rich nutty flavour, sweet taste, crunchy texture and over and above a relatively longer shelf life (Anonymous, 2022).

Peanut is a major oilseed crop of India. However, unlike other oilseeds, groundnut can be consumed directly as food. With the growing awareness among people about the importance of balanced diet, demand for low calorie-high protein foods is increasing as people tend to avoid consumption of high-fat foods lest it should cause obesity and associated health problems (Blundell and Macdiarmid, 1997; Kuller 1997).

The peanut is a main crop in Saurashtra region of Gujarat, where it is one of the most affordable protein sources. Peanuts are crucial as an oil-bearing seed globally, rapidly becoming a valuable plant protein source. The seeds provide protein, lipids, and fatty acids essential for human nutrition (Tai and Young, 1975; Gaydou *et al.*, 1983).

Peanuts rank fifth globally in vegetable oil production, with the by product, peanut oil cake or meal, used post-oil extraction (Kain *et al.*, 2009). Processed into partially defatted peanut flour (DPF), it retains protein richness (47-55%) and essential amino acids, making it ideal for diverse food applications (Kain *et al.*, 2009; Rehrah *et al.*, 2009; Ma *et al.*, 2010). The nutritive value of any peanut product is closely associated with the fatty acid composition of its oil content, which influences its quality (Dhamsaniya *et al.*, 2012).

The utilization of defatted peanut meal in food products offers a promising approach to increase groundnut protein consumption. It can be incorporated as a low-fat groundnut concentrate, composite flour, or functional ingredient in various food items such as bakery products, breakfast cereal flakes, snack foods, multipurpose supplements, infant and weaning foods and extruded meals (Vyas *et al.*, 2023).

In India, peanut flour is used to make a variety of low-cost new food product formulations. The pleasant aroma, nutty flavour and smooth texture of roasted nuts have gained popularity. The earlier studies reported many health benefits of peanuts. Peanut is utilised to improve nutrients in traditional food products and to cure severe child malnutrition. Consumers in India are becoming more health conscious and looking for healthy food due to rising disposable income, education levels and nutritional understanding (Sejani *et al.*, 2022).

Defatted peanut flour: nutritional and functional properties

Defatted Peanut Flour (DPF) is increasingly recognized for its nutritional and functional properties, making it a valuable ingredient in various food applications. This response synthesizes the nutritional composition and functional benefits of DPF, particularly in the context of extrusion processes. Defatted peanut flour is characterized by a high protein content, typically ranging from 47% to 55%, which is significant for dietary protein intake (Kain and Chen, 2010). This flour is also rich in essential amino acids, particularly arginine, making it an excellent protein source for fortifying various food products (Ukeyima *et al.*, 2021). The removal of lipids during the defatting process not only reduces the caloric content but also enhances the nutritional profile by concentrating proteins and dietary fibers. Additionally, DPF contains important micronutrients such as thiamin, niacin, folate, potassium, and magnesium, which contribute to its overall health benefits (Seth and Kochhar, 2017).

Table 1 : Chemical composition of defatted peanut flour (Chocha *et al.*, 2024).

S. no.	Characteristics	Value
1	Moisture content (%w.b.)	5.30
2	Carbohydrate (%)	26.69
3	True protein (%)	59.15
4	Fat (%)	5.91
5	Ash (%)	4.67

The carbohydrate composition of DPF is relatively low, which is advantageous for those seeking to reduce carbohydrate intake while maintaining protein levels (Oyedoh *et al.*, 2020). The presence of soluble sugars, primarily sucrose, has been noted, indicating that DPF retains some of the natural sugars found in peanuts, which can enhance flavor and sweetness in food formulations (Cohen, 2023). Furthermore, the functional properties of

DPF, such as emulsification capacity and gelation ability, are influenced by its protein structure, which can form stable emulsions and gels, essential for various food applications (Osuolale and Olayiwoola, 2014).

The functional properties of defatted peanut flour make it particularly suitable for extrusion processes. Extrusion cooking is a method that combines heat and moisture to transform food materials, and the inclusion of DPF can significantly enhance the nutritional and sensory qualities of extruded products. Studies have shown that the addition of DPF improves the overall quality of gluten-free products, such as cookies and breakfast cereals, by increasing protein content and enhancing texture (Wang and Wu, 2022). The high protein content of DPF contributes to the structural integrity of extruded products, allowing for better expansion and a desirable mouthfeel (Zhao *et al*., 2011).

Moreover, DPF exhibits excellent emulsifying properties, which can be beneficial in creating stable emulsions during the extrusion process. This is particularly important in products that require uniform texture and consistency, such as snacks and pasta. The ability of DPF to form gels also plays a crucial role in providing a matrix that holds water and other ingredients, thereby improving the moisture retention and shelf-life of extruded products (Osuolale and Olayiwoola, 2014). Defatted peanut flour is a nutritionally dense ingredient that offers numerous functional benefits, particularly in extrusion applications. Its high protein content, combined with favorable emulsifying and gelling properties, makes it an ideal choice for enhancing the nutritional profile and sensory attributes of various food products.

Extrusion technology process parameters

The effectiveness of the extrusion process is significantly influenced by various parameters, including temperature, moisture content and screw speed. Each of these factors plays a critical role in determining the physical and nutritional characteristics of the extrudates. Temperature is one of the most critical parameters in the extrusion process. It affects the viscosity of the material, the degree of gelatinization of starches, and the extent of protein denaturation. Higher extrusion temperatures generally promote the Maillard reaction, which can enhance flavor but may also lead to the degradation of essential amino acids (Bartkiene *et al*., 2021). Studies have shown that optimal temperature settings can improve the expansion and texture of extrudates, while excessively high temperatures can compromise the nutritional quality of the final product (Gulati *et al*., 2015). For instance, the physicochemical properties of extruded rice bran were significantly altered by varying the extrusion temperature, impacting both texture and nutrient retention (Gao *et al*., 2022).

Moisture content is another vital parameter that influences the extrusion process. It affects the cooking degree of the material and the shear forces experienced during extrusion. Higher moisture levels can lead to increased expansion and improved texture of the extrudates, as they facilitate the gelatinization of starches and the solubilization of proteins (Gulati *et al*., 2015). Conversely, low moisture content can result in undercooked products with poor texture and expansion (Yadav *et al*., 2022). The interaction between moisture and temperature is crucial, as it determines the extent of cooking and the final characteristics of the extrudate (Asare *et al*., 2011).

Screw speed is a parameter that influences the residence time of the material within the extruder, affecting the degree of mixing and shear applied to the ingredients. Increased screw speed can enhance the shear forces, leading to better mixing and a more uniform product (Gulati *et al*., 2015). However, excessively high screw speeds may lead to increased friction and heat generation, potentially causing thermal degradation of sensitive components (Asare *et al*., 2011). The optimization of screw speed is essential for achieving the desired texture and expansion in extruded products.

The relationship between extrusion temperature and nutrient retention is complex. While higher temperatures can enhance the flavor and texture of extrudates, they can also lead to the loss of heat-sensitive nutrients, such as vitamins and certain amino acids. For example, the amino acid profile of extrudates can be adversely affected by elevated temperatures, which may lead to a reduction in the nutritional quality of the product (Bartkiene *et al*., 2021). Therefore, it is crucial to balance the benefits of higher temperatures in terms of product quality with the potential losses in nutritional value. Research indicates that optimizing extrusion parameters, including temperature, can help retain essential nutrients while still achieving desirable sensory attributes in the final product (Yadav *et al*., 2022). The extrusion process is a multifaceted technology that relies on the careful manipulation of various parameters, including temperature, moisture content and screw speed, to produce high-quality food products. Understanding the influence of these parameters is essential for optimizing the extrusion process and ensuring the retention of nutritional value in the final extrudates.

Impact on product quality

The physicochemical properties of defatted peanut flour significantly influence the quality and functionality of extruded products. Defatted peanut flour, obtained from roasted peanuts through oil extraction, retains a high protein content, typically ranging from 45% to 50% on a dry weight basis, while exhibiting a reduced fat content. This alteration in fat content not only decreases the caloric density but also enhances the flour's rheological properties, water absorption capacity and emulsifying ability, which are critical during the extrusion process (Martin *et al.*, 2021; Ukeyima *et al.*, 2021). The moisture content of defatted peanut flour, generally between 6% and 10%, plays a pivotal role in determining the shelf life and quality of extruded products. Lower moisture levels can inhibit microbial growth and enzymatic spoilage, although it is crucial to maintain an optimal moisture balance during extrusion to prevent defects such as puffing or collapse (Ukeyima *et al.*, 2021).

The protein content in defatted peanut flour contributes significantly to the nutritional profile and functional properties of extruded products. The predominant globulins in the flour exhibit good solubility, facilitating interactions with other ingredients during extrusion, which can enhance texture and mouthfeel. Additionally, the pH of defatted peanut flour, typically ranging from 6.5 to 7.5, is conducive to protein stability and can influence solubility, functionality, and flavor profile of the final product. For instance, a neutral pH is often preferred for flavor balance, while a more acidic pH may enhance certain flavors. Furthermore, the particle size distribution of defatted peanut flour is critical; finer particles improve flowability and dispersibility, leading to a more uniform mixture and enhanced texture in the final product (Ukeyima *et al.*, 2021; Bongjo *et al.*, 2022).

Extrusion processing conditions, including temperature, pressure, and shear, interact with these physicochemical properties to further influence product quality. Higher extrusion temperatures can promote protein denaturation, enhancing functional properties but potentially leading to nutrient loss if not controlled (Ukeyima *et al.*, 2021). The shear forces during extrusion also affect starch gelatinization and overall texture, underscoring the importance of understanding these interactions for developing high-quality extruded products that leverage the nutritional benefits of defatted peanut flour (Ukeyima *et al.*, 2021; Bongjo *et al.*, 2022).

In terms of sensory evaluation, the organoleptic properties of extruded products made with defatted peanut flour are crucial for consumer acceptance. Key sensory attributes include appearance, aroma, flavor, texture, and overall acceptability. The appearance of extruded products is often characterized by a golden-brown color, resulting from the Maillard reaction during extrusion, which can vary based on processing conditions (Martin *et al.*, 2021; Ukeyima *et al.*, 2021). Aroma, influenced by the roasting process of peanuts, contributes to the sensory experience; however, care must be taken to avoid off-flavors from excessive heat or prolonged processing. Flavor is a critical determinant of consumer preference, with defatted peanut flour imparting a distinct nutty flavor that can be enhanced with complementary ingredients (Ukeyima *et al.*, 2021; Bongjo *et al.*, 2022).

Texture, ranging from crunchy to chewy, is another vital sensory characteristic that affects consumer acceptance. The protein and fiber content in defatted peanut flour enhances textural properties, contributing to chewiness and mouthfeel. Sensory evaluation panels assess attributes such as crispness and hardness to gauge overall acceptability, which is often quantified using hedonic scales (Ukeyima *et al.*, 2021; Bongjo *et al.*, 2022). Overall acceptability reflects the consumer's impression of the product, emphasizing the need for comprehensive sensory analyses during product development to align with consumer preferences (Martin *et al.*, 2021; Ukeyima *et al.*, 2021). The impact of defatted peanut flour on the quality of extruded products is multifaceted, encompassing both physicochemical properties and sensory evaluation. Understanding the interplay between these factors is essential for developing high-quality products that meet nutritional standards and satisfy consumer preferences. As the demand for healthier food options rises, the exploration of defatted peanut flour in extruded product development presents a promising avenue for innovation in the food industry. Future research should focus on optimizing processing conditions, enhancing sensory attributes, and exploring novel formulations to fully leverage the functional and nutritional benefits of defatted peanut flour in extruded products.

Nutritional enhancements and health benefits of defatted peanut flour

Improved Protein Quality

Defatted Peanut Flour (DPF) is recognized for its high protein content, typically ranging from 47% to 55%, which significantly enhances the nutritional profile of various food products. The protein quality of DPF is attributed to its rich essential amino acid composition, making it an excellent source of plant-based protein for fortifying gluten-free and composite flours (Kain and Chen, 2010; Wang and Wu, 2022). Studies have demonstrated that incorporating DPF into baked goods, such as cookies and bread, not only increases the protein content but also improves the overall nutritional value of these products (Wang and Wu, 2022; Bongjo *et al*., 2022). For instance, the addition of DPF in gluten-free cookies has been shown to significantly enhance their nutritional and functional quality, making them more appealing to health-conscious consumers (Wang and Wu, 2022).

Moreover, the incorporation of DPF into various formulations can lead to improved texture and mouthfeel, which are critical for consumer acceptance. The protein in defatted peanut flour contributes to the structural integrity of baked goods, allowing for better moisture retention and a more desirable texture (Kain and Chen, 2010; Bongjo *et al*., 2022). This enhancement in protein quality is particularly beneficial for individuals seeking to increase their protein intake without relying on animal sources, thereby supporting dietary preferences such as vegetarianism and veganism (Singh *et al*., 2021).

Reduction of Anti-Nutritional factors

The presence of anti-nutritional factors, such as phytic acid and tannins, in legumes and oilseeds can limit their nutritional benefits. However, various processing methods, including roasting, germination, and fermentation, have been shown to effectively reduce these anti-nutritional factors in defatted peanut flour (Embaby, 2010; Makinde and Dauda, 2020). For example, heat treatments can significantly decrease the levels of phytic acid, which is known to inhibit mineral absorption, thereby enhancing the bioavailability of essential nutrients in the flour (Embaby, 2010).

Additionally, the processing of peanuts into defatted flour not only reduces fat content but also diminishes the levels of certain anti-nutritional compounds, making the flour a healthier option for consumers (Makinde and Dauda, 2020). This reduction is crucial as it allows for better absorption of minerals such as iron and zinc, which are often hindered by the presence of phytic acid. Furthermore, the nutritional quality of products made with defatted peanut flour can be significantly improved, as the flour can be combined with other ingredients to create nutritionally superior formulations (Bongjo *et al*., 2022; Ukeyima *et al*., 2021). Defatted peanut flour serves as a valuable ingredient in food formulations due to its high protein quality and the ability to reduce anti-nutritional factors. These attributes not only enhance the nutritional profile of various food products but also contribute to better health outcomes for consumers. The ongoing exploration of defatted peanut flour in food science highlights its potential as a functional ingredient that meets the growing demand for nutritious and health-promoting food options.

Applications in Food Product Development

Defatted Peanut Flour (DPF) has emerged as a valuable ingredient in the development of healthy snacks and gluten-free products. Its high protein content, typically ranging from 47% to 55%, enhances the nutritional profile of gluten-free formulations, making them more appealing to health-conscious consumers (Wang and Wu, 2022). For instance, studies have shown that incorporating DPF into gluten-free cookies significantly improves their overall nutritional and functional quality, allowing for the creation of products that are not only rich in protein but also maintain desirable sensory attributes (Wang and Wu, 2022; Seth and Kochhar, 2017). The addition of DPF at levels of 10-15% has been particularly effective in enhancing the texture and flavor of gluten-free baked goods, such as cookies and bread, while also providing a source of healthy fats and dietary fiber (Seth and Kochhar, 2017).

Moreover, DPF can be utilized in the formulation of various snack products, including protein bars and baked snacks, where it contributes to both nutritional enhancement and improved texture (Rachman *et al*., 2019). The incorporation of DPF in gluten-free pasta has also been explored, with findings indicating that it can improve the nutritional value while maintaining acceptable sensory characteristics (Udachan *et al*., 2022). This versatility makes DPF an excellent choice for manufacturers aiming to meet the growing demand for gluten-free and health-oriented snack options.

Beyond snacks and gluten-free products, defatted peanut flour has potential applications in a variety of food products. Its functional properties, such as emulsification, water absorption, and thickening capabilities, make it suitable for use in sauces, dressings, and baked goods (Kain and Chen, 2010). For example, DPF can be incorporated into bread formulations to enhance protein content and improve moisture retention, resulting in a product with better shelf life and texture (Adeboye *et al*., 2017). The use of DPF in composite flours, combined with other gluten-free ingredients, has been shown to yield products with improved sensory qualities and nutritional benefits, making it a valuable ingredient in the development of gluten-free baked goods (Rachman *et al*., 2019; Bravo Nunez *et al*., 2020).

Additionally, DPF can be utilized in the production of meat alternatives and vegetarian products, where it serves as a protein source that mimics the texture of meat. This application is particularly relevant in the context of rising vegetarianism and veganism, as consumers seek plant-based options that do not compromise on taste or texture. Furthermore, the antioxidant properties of defatted peanut flour, attributed to its residual phenolic compounds, can enhance the nutritional value of fortified foods, making it a promising ingredient for health-focused product development (Asen *et al*., 2021).

Defatted peanut flour offers a multitude of applications in food product development, particularly in the creation of healthy snacks and gluten-free products. Its high protein content, functional properties and versatility make it an attractive ingredient for manufacturers looking to innovate and meet consumer demands for nutritious and healthful food options. Future research should continue to explore the potential of DPF in various formulations, aiming to optimize its use in diverse food products.

Conclusion

Incorporating Defatted Peanut Flour (DPF) into extruded products offers substantial functional and nutritional benefits, making it a promising ingredient for developing health-conscious foods. Its high protein content, essential amino acids and favourable physicochemical properties contribute to improved texture, expansion, and nutrient retention in extruded snacks, protein bars and gluten-free products. Moreover, the ability of DPF to enhance protein quality, reduce anti-nutritional factors, and positively influence extrusion parameters underscores its value in food product innovation.

Extrusion technology, when optimized, allows for the development of nutrient-rich, appealing products that align with consumer demand for healthier, functional foods. As the food industry continues to evolve, exploring the full potential of DPF in extrusion applications can open new avenues for creating innovative, sustainable, and nutritious food options. Future research should focus on optimizing extrusion parameters, expanding applications, and enhancing sensory attributes to fully leverage the potential of DPF in food product development.

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