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A review: Indian innovations in millet-based extruded products

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ABSTRACT

Millets are an important crop for most of them of farmers with small land holdings in terms of agricultural practises, health and nutritional security, and climate change. These days, many prefer extruded snacks over conventional ones, especially when they are ready to consume. Most commercially available snacks are mostly made of cereal, which is a decent source of carbs but deficient in protein and other minerals like iron. For this reason, it's critical to change the ingredients used to produce snacks in order to provide balanced nutrients like minerals and protein. Millets are the least priced and highest protein grain, thus using them will address this problem. Thus, an endeavour was made to develop a snack based on millet by combining several types of millets, such as sorghum, oats, and green gramme, and investigating the characteristics of these millets. Extrusion is a versatile, cutting-edge technique that has the ability to significantly alter how food ingredients work in order to improve digestibility and sensory quality. The food enterprise, scientists, and processors/consumers may select the optimal processing technique to maximise nutritional content, increase nutrient bioavailability, and support nutrition security by having a better understanding of how processing impacts millets' nutrient content. In this study, we focus on recent developments in the production of millet and pulse-based extruded foods. Additionally, the use of extruded flours as novel, environmentally friendly ingredients-such as hydrocolloids and fat substitutes-as well as for the creation of gluten-free, phenolic-rich, low-glycemic, and functional meals has been examined.

Key words : Millet, Extrusion, Nutritional benefit.

INTRODUCTION

In the realm of agriculture and nutrition, millets have emerged as a vital crop, offering solutions to various contemporary challenges such as climate change, health and nutritional security, and sustainable agricultural practices, particularly for modestly sized farmers with small land holdings (Choton*et al.*, 2020; Navale*et al.*, 2015; Shelar*et al.*, 2019). In today's fast-paced world, the preference for extruded snacks, particularly those that are ready to eat, has seen a significant rise. However, many of these snacks are primarily composed of cereals, rich in carbohydrates but lacking in essential nutrients like protein and minerals, such as iron. This nutritional imbalance has raised concerns regarding the health impact of popular snack choices (Bordoloiet *al.,* 2014;Kumaret *al.,* 2018).The solution to this dilemma lies in reimagining the raw materials used in snack production to ensure a balanced nutrient profile, rich in protein and minerals. Millets, with their remarkable affordability and high protein content, offer a promising alternative. A concentrated effort has been made to develop millet-based snacks in answer to this requirement, utilising a variety of millet combinations, such as sorghum, oats, and green gram(Amadouet *al.,* 2013;Chandra *et al.,* 2016;Taylor *et al.,*2006). These creative concoctions aim to maximise the inherent properties of these hardy grains, abundant in nutrients and adaptability. (Azmiretal., 2013; Taylor *et al.,*2008).The process of extrusion, a dynamic and inventive technique with enormous potential to improve the digestibility and sensory quality of food ingredients, is essential to this transition. Researches and customers alike must comprehend how processing methods affect the nutritional value of millets in addition to the food sector. (Assadpouret *al.,* 2019; Mohammed *et al.,* 2020). It enables informed choices in processing methods that maximize nutrient retention and bioavailability, ultimately contributing to improved nutrition security (Jaybhayeet *al.,* 2014; kumaret *al.,* 2021).This review delves into recent advancements in the production of extruded products, crafted from the bounty of millets and pulses. Additionally, the exploration of extruded flours as innovative green components, serving as hydrocolloids, fat substitutes, and as a foundation for the creation of gluten-free, phenolic-rich, low glycemic, and functional meals, underscores the multifaceted potential of these ancient grains (Kumar *et al.,* 2018; Pasqualoneet *al.,* 2020). As we embark on this journey through the realms of millet-based snack production and extraction techniques, we uncover not only a realm of nutrition-enhancing possibilities but also a pathway to a more sustainable and wholesome future in food innovation (Arribaset *al.,* 2017;Chotonet *al.,* 2020).

Process flow for various millets based extruded products

Various millets-based extruded products have gained prominence in the food industry due to their nutritional benefits and versatility. The production of these extruded products involves a combination of extrusion technology and the unique characteristics of different millets. Here are a few methods for making extruded items made from millets:

Extrusion technology for various millet based products

The food industry can use modified extruded flours for a variety of purposes, including thickening, gelling, functional additives, and fat replacement (Mohammed *et al.,*2020; Saini *et al.,*2021).The processing of wheat, corn, and rice flours for the creation of ready-to-eat snack goods has made extensive use of extrusion cooking. From a nutritional perspective, they are paradoxically heavy in fats and carbohydrates and low in dietary fiber, which results in a high glycemic load. This is well recognized to induce type 2 diabetes and pediatric obesity (Arribaset *al.,*2017;Burešováet *al.,*2017).

To qualify as functional foods, snacks must be enhanced with high levels of protein, dietary fiber, minerals, and phenolics. Using organically derived food items like pulses, whole grains, millets, pseudocereals, and other items is a great way to create useful snacks. Millets have favourable outcomes on blood lipids and glucose, reduce the possibility of cardiovascular disease and several malignancies, and enhance insulin resistance (Kauret *al.,*2014). As a result, millets are a great way to add more nutritional fiber to prepared foods. To increase the amount of dietary fibre in extruded goods ata lower cost than adding purified fiber, millet flours can be used. (Wojtowicz *et al.*,2015).

Using components made of extruded flours aids in the management of type 2 diabetes and the glycemic response. Extrusion processing is one way to modify starch digestibility, and it is believed to be a major factor in modifying the glycemic response. Regarding the starch digestibility of extruded items, there are now two opposing theories that are generally acknowledged.As stated by thefirst theory, foods that are extruded fall under the high glycemic index (GI) food category. (Onwulata*et al.*,2010).This depends on the finding that starch fragmentation and partial gelatinization (Cabrera-Chavez *et al.*,2012), Proteins with altered structures and conformations are often more digestible. Because the depolymerization process makes starch easier for amylolytic enzymes to access during digestion, extruded snack items frequently have a greater glycemic rather than their unfiltered, unprocessed component equivalents. On the other hand, the second idea classifies them as low GI foods. This is due to the fact that extrusion also alters the starch's structure, producing less substantial amylose and amylopectin units that may combine to form new, indigestible bonds and lower the GI..(Liu *et al.*,2015). Strong evidence points to the formation of amylose-lipid complexes in these processes.

Effect of various processing methods

Given the threat to global food security, it is imperative that we make effective use of the millet crops that are now accessible to produce a nutrient-rich, aesthetically pleasing, and reasonably priced product. To separate the unsuitable portions and transform the millet grains into cooked and consumable form, processing is required. Processing is consequently necessary since it increases the absorption of vitamins and minerals and their organoleptic compounds characteristics while reducing antinutrients. There are two types of processing that can be done: principal and secondary. Primary processing involves removing anti-nutritional elements and unwanted seed coat through cleaning, soaking/germination, de-hulling, milling (to make flour and semolina), and refining. Secondary processing involves using flaking, popping, extrusion, and baking to turn primary processed raw materials into "ready-to-cook" (RTC) or "ready-to-eat" (RTE) products. (Rao *et al.*,2017).

De-branning, milling, roasting, soaking, steaming germination, popping, flaking, salted grains that are ready to eat, and fermented goods are examples of traditional processing techniques.

The goal of these processing methods is to transform grains into consumable forms that have better texture, taste, and unique flavor as well as increased digestibility and nutritional value. (Yousaf*et al.*,2021). Processing millet into different by-products can boost its consumption and use while lowering its levels of phytate and tannin, increasing the bioavailability of minerals and amino acids, and improving the digestibility of starch and protein. (Deshpande*et al.*,2015).

These bioactive substances found in in entire grains undergo particular physiological, structural, or alteredconsequently of processing. The processing methods may have both positive and negative effects on the nutritional and anti-nutrient composition. Numerous investigations on millet Studies have demonstrated the benefits of using millet in a range of conventional and quick-to-prepare nutritious foods. Trypsin inhibitors, tannins, phenols, and significant amounts of phytates reduce the quality and absorption of nutrients, preventing millets from reaching their full nutritious potential (Rao*et al.*,2017). Because some millets have larger levels of fats that aren't saturated than others, sourness and off tastes can develop in millet flour over time as consequently of lipolysis and oxidation of "de-esterified fatty acids."(Bora*et al.*,2019). To allow millet to be used effectively, it is crucial to comprehend how processing affects their nutritional qualities. It also helps in selecting the right processing method for millet to be able to enhance palatability, optimize nutrient availability, and lengthen shelf life (Gowda*et al.*, 2022).

DISCUSSION

Extrusion Technology

In the 1870s, extruders were created to produce sausage. The 1930s saw the development of the single-screw extruder, which was used to combine semolina flour with water to create pasta products. It was also used to mold hot, precooked dough for the production of ready-to-eat (RTE) cereals. The amount of shear rate was minimal in each of these situations. Directly expanded maize curls were made in the late 1930s and early 1940s with extruders, which had very high shear rates. In the middle of the 1950s, the first patent application utilising twin-screw extrusion technique was submitted. Since then, there has been a significant advancement, expansion, and growth in the use of extrusion technology in food processing. (Rao *et al.*,2015).

Five major components make up an extruder: the die and cutting mechanism; the barrel; the screw or worm; the feeding system; the pre-conditioning system; and the barrel. Regarding screw, barrel, and die configuration, they might differ. The choice of each of these products will rely on the intended end result and the raw material utilized. (Riaz, 2000).

The basic principles of extrusion involve feeding raw ingredients into the barrel of the extruder, followed by the screw (s) that move the food along it. Smaller flights further down the barrel limit the volume and heighten the food's resistance to movement. It becomes squeezed as a result of filling the barrel and the gaps between the screw flights. The material is worked by the screw into a semi-solid, plasticized mass as it travels down the barrel. Extrusion cooking, sometimes referred to as hot extrusion, is the method of heating food beyond 100ºC.

The food industry can use modified extruded flours for a variety of purposes, including thickening, gelling, functional additives, and fat replacement. The potential of extruded flours as functional snacks, morning cereals, and additions in millet-based extruded goods has been critically highlighted in recent publications. Using extrusion to create useful treats the processing of wheat, corn and rice flours for the creation of ready-to-eat snack goods has made considerable use of extrusion cooking.From a nutritional perspective, they are paradoxically heavy in fats and carbohydrates and low in dietary fibre, which results in a high glycemic load. This is well recognized to induce type 2 diabetes and paediatric obesity.

The glycemic index of morning cereals made via extrusion can be lowered by using non-traditional cereal flours like amaranth, buckwheat, or millet, according to recent study articles. Higher bulk and product density, a comparable expansion ratio, and "a significant reduction in readily digestible carbohydrates and slowly digestible carbohydrates" are all present in the extruded made utilizing these grain flours. According to another study, "the rate and extent of carbohydrate hydrolysis of the extruded products" is significantly reduced when dietary fibre is added to the extruded breakfast cereal mix in place of 5% to 15% of wheat flour and white flour. This increases the amount of slowly digested carbohydrates and decreases the amount of quickly digested carbohydrates.

Using extruded flours as components helps control type 2 diabetes and the glycemic response. Starch digestibility may be adjusted by extrusion processing, and this is thought to be a key component in adjusting the glycemic response. There are now two competing ideas that are widely accepted about the starch digestibility of extruded goods. According to the first idea, foods that are extruded fall within the high glycemic index (GI) food group. This is predicated on the observation that protein structural and conformational alterations, as well as partial gelatinization, often enhance overall digestibility. When starch is depolymerized, it becomes easily accessible to amylolytic enzymes during digestion. As a result, extruded snack items often have a greater glycemic response than their raw, unprocessed component counterparts. Conversely, the second idea classifies them as low GI meals.

To be considered functional foods, snacks must be enhanced with high levels of protein, dietary fibre, minerals, and phenolics. An advantageous time to make functional snacks is when whole grains, millets, pulses, pseudo cereals, and other organically derived components are used. These days, pulses are regarded as useful gluten-free grains with high nutritional fibre content and complex carbs, which results in a low glycemic index in extrusion formulations. The evaluation of pulses (soybean, chickpea, beans, peas, lentils, etc.) for extruded snacks has received a lot of attention in recent years. Extruded pulses are thought to be very viable for the production of high-nutrient, low-calorie snacks with additional value because of reports of their excellent growth.Millets have positive effects on blood lipids and glucose, reduce the risk of cardiovascular disease and several malignancies, and enhance insulin resistance. As a result, millets are a great way to add more nutritional fibre to prepared foods.

To increase the nutritional fibre content of extruded goods at a lower cost than adding purified fibre, millet flours can be used. Healthy food enthusiasts can find natural fruit or vegetable colours in extruded items appealing. Here, natural colours have been added to dried fruit powders high in anthocyanins and carotenoids to enhance the colour appeal and overall antioxidant benefit of extrudates.

This is because extrusion also modifies the structure of starch, resulting in smaller amylose and amylopectin units that may cross link to generate new, indigestible connections and reduce the GI. Strong evidence points to the formation of amylose-lipid complexes in these processes. Numerous variables, including the degree of starch gelatinization, the kinds of native crystalline structures, the ratio of amylose to amylopectin, and the development of complexes between starch and lipid or protein or resistant starch, influence the GI of starch-based foods that are extruded.

Short-duration, high-temperature extrusion "minimises losses in vitamins and amino acids". Some foods may be produced in large quantities using extrusion, which also "denatures anti-nutritional factors" including poisons and microbes. It also has an impact on the product's form, texture, colour, and flavour, and may enhance "protein quality and digestibility". Moreover, it may break down proteins, starches, and non-starch polysaccharides to produce "reactive molecules that may form new linkages not found in nature." This includes Maillard processes, which lessen the proteins' nutritious content. Heat-labile vitamins might be damaged. Moderate circumstances (short time, high moisture, low temperature) have been reported to increase nutritional quality

CONCLUSION

Millets are comparable in energy content to ordinary grains. They are rich in fibre, minerals, vitamins, macro- and micronutrients, and phytochemicals. They can help cure chronic conditions and provide more significant health benefits. Prepared millet is an economical, filling, and beneficial dinner option when incorporated into a daily diet. It was discovered that during germination and fermentation, the nutritional fibre, mineral, and vitamin contents of the majority of millets rose. In the fight against protein-energy malnutrition, straightforward processing techniques including soaking, germination/malting, and fermentation can boost protein digestibility and increase mineral absorption. Considering the range of ways that processing alters the nutritional properties of millets, attention ought to be focused on refining the techniques for processing smaller millets in order to boost their appeal while preserving their health advantages. Based on the reviewed literature, it is reasonable to conclude that extrusion is a very flexible and promising technology, and that it should be seen more widely as a groundbreaking way to produce better functional meals that go beyond the usual extruded snack alternatives. Extrusion offers a wonderful technique to modify the hydration properties and improve paste stability and food matrix performance by varying the processing settings.

The barrel's temperature and pressure, the die aperture diameter, and the product shear rate are critical operational parameters. The speed and geometry of the screw (the size, quantity, pitch, and diameter of the flights) as well as the internal barrel design, which includes grooves or limitations (referred to variously as "throttle rings," "kneading discs," or "shearlocks"), all have an impact on the shear rate. A steam-jacketed barrel, a steam-heated screw, or electric heating components around the barrel can all offer further warmth.

Extrusion has "revolutionised many conventional snack manufacturing processes" and made it possible to produce new processed food items. Extrusion produces a variety of food items, most of which have a high starch content. Corn curls and morning cereals are examples of directly expanded forms that are produced under high shear, low moisture and high temperature circumstances. Pasta is an example of a non-expanded product; it is made at a low temperature and an intermediate moisture content (about 40%). Fish paste and meat analogues, which are produced with "textured vegetable protein" derived from plants and a lengthy die to "impart a fibrous, meat-like structure to the extruded," are examples of items that have been texturized. Candy produced by extrusion includes licorice, toffee, and chewing gum.Some breads (such as croutons, bread sticks, and flat breads), other ready-to-eat snacks, pre-made cookie dough, some infant meals, some drinks, and dry and semi-moist pet foods are among the other food items that are frequently manufactured by extrusion. Macaroni, jelly beans, sevai, and certain french fries are some specific examples. Additionally, extrusion is used to pellet animal feed and alter starch.

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