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Exploring the Potential of Extruded Products as Raw Material for Sports Food

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Abstract

Sports food products are becoming increasingly popular among athletes and fitness enthusiasts. These products are intended to improve performance, ease recuperation, and promote general health and wellbeing. Extruded food products are gaining favor as a raw material for sports food preparation owing to their nutritional content, simplicity, and variety. In the present study a co-rotating twin-screw extruder was used to produce protein rich extruded Crispies from a mixture of maize flour, ragi flour, gram flour, and then enriching the flour blend with soy protein isolate (SPI). The ratio of cereal to pulses was maintained at 4:1. This formulation yields 395 Kcal of energy, 25.39 g of protein, 68.36 g of carbohydrates, 2.24 g of crude fat, 8.54 g of moisture, and 2.26 g of ash per 100 g of Crispies. The protein content of the Crispies showcased in the results makes them a suitable raw material for producing nutrient-dense protein-energy bars that offer dietary variety, especially for athletes who require high-protein diets for optimal performance. 12% of these crispies were used as a raw material in the standardization of the formula for Protein-Energy Bars.

Keywords

Cereal-Pulses, Crispies, Protein Bars, Soy Protein Isolate, Sports food, Twin Screw Extruder.

INTRODUCTION

Athletes have unique nutritional needs due to the high physical demands of their training and competition. They require optimal amounts of macronutrients (carbohydrates, protein, and fat) and micronutrients (vitamins and minerals) to support their energy metabolism, muscle growth and repair, and immune function. Carbohydrates are a primary fuel source for endurance exercise and high-intensity activities. Protein is necessary for muscle protein synthesis and repair, especially after resistance training. Fat provides a concentrated source of energy and helps support hormonal balance. Athletes must fuel their bodies with the appropriate nutritional foods to meet their energy requirements in competition, training, and recovery. If these nutritional needs are not met, there is an increased risk of poor performance and health issues [1]. *Sports foods* are "food products that are created and marketed for the purpose of being consumed by athletes, with formulations that are tailored to meet their nutritional needs and support their physical performance." They are designed to meet these nutritional requirements by providing convenient and targeted sources of macronutrients and micronutrients [2].

Protein Bars

Many athletes utilize nutritional supplements as part of their usual training or competing regimen. Convenience supplements (e.g., energy bars, meal replacement powders, ready-to-drink supplements) are intended to give a quick and easy way to fulfil caloric demands and/or manage caloric intake, weight gain, weight reduction, and/or performance improvement [3]. Protein bars are specifically formulated for athletes and body builders to provide extra protein, ranging from 20-35 grams per bar, which helps them gain energy during strenuous exercise. Protein bars often include a combination of macronutrients including protein, carbs, and fat, as well as additional nutrients like fiber, vitamins, and minerals. They may be created with a variety of components for different food groups, including grains, protein sources such as whey, soy, casein, and pea protein, sweeteners, nuts and seeds, dried fruits, flavors, and preservatives to improve taste and acceptability, as well as shelf life.

Whole-grain diets are becoming more popular due to their various health advantages, such as being a good source of dietary fiber, antioxidants, and vitamins. Cereals, on the other hand, are low in the important amino acid lysine, resulting in poor protein quality. Because legumes and pulses are high in lysine, including them into the diet may improve the overall protein quality of cereals. Cereal protein, on the other hand, supplements pulse protein in the important amino acid methionine. Combining these lysine-deficient cereals with other plant-based lysin rich pulse proteins, such as gram and soy protein isolate, may improve the final product's protein quality.

Extrusion

Extrusion cooking is part of the HTST (High temperature short-time) method, which was developed for the development of innovative value added RTE (ready to eat) food products made from grains and cereals, such as infant foods, dietary fibers, cereal-based breakfast products, cereal-based modified starch food products, pet foods, and

traditional food products. Extrusion process is economically viable, flexible, and versatile as it has lower processing cost than other cooking methods and it has continuous processing capability. In food industry, extrusion cooking is a process that is to transform protein-based dough or mixture into snacks and breakfast cereals. The mechanical energy produced by the primary motor is generally isolated from the thermal energy supplied by the heating system [4].

During extrusion processing of food, Starches are gelatinized, proteins are denatured, nutrient inhibitors are inactivated, fat breaking enzymes are deactivated, and the food is pasteurized, resulting in a longer shelf life [5]. Furthermore, since it uses the HTST technique of processing, it does not impart cooked taste to the food but rather offers it texture and crispiness. Extruded products made from cereal and pulses combination can be used as a raw material for sports food preparation due to their high protein content, low-fat content, and good digestibility.

Proteins are also employed in extrusion for two key reasons: structure and nutrition. As protein concentration decreases, the protein becomes more diluted, making any structure or texture formed by the protein less visible in the result. Texturization requires a minimum protein level of 30% [6]. This justifies incorporating SPI to the cereal-pulses combination in the extrusion feed.

This paper aims to discuss the development and utilization of extruded products-Crispies made from, maize (Zea mays) flour, ragi (Eleusine coracana) flour and gram (Cicer arietinum) flour and soy protein isolate (SPI) in the preparation of protein-energy bars for athletes.

MATERIAL AND METHODS

Selection of raw material and chemicals:

- The selection of raw materials is the prime stage for an effective extrusion process since it defines the quality of the end-product. Maize (Zea mays) flour, ragi (Eleusine coracana) flour and gram (Cicer arietinum) flour were procured from the local market of Anand, Gujarat, India. Soy protein isolate (SPI), NAKPRO brand, was supplied by NAKPRO Nutrition, Bengaluru, via online purchase. According to one research, including common bean (Phaseolus vulgaris L) flour into maize starch-based extruded snacks enhanced protein and dietary fiber levels, improving the nutritional profile of the snacks [7]. Packaging material, low-density polyethylene (LDPE) pouches were purchased from a local store at Anand, Gujarat, India. All the chemicals used in the preparation of different reagents were of Analytical Grade (AR), were freshly prepared adopting the standard procedures and were procured from standard companies.

Methods

Preparation of feed mixture formula:

A cereal and pulses combination of 4:1 was used to enhance protein content and quality in terms of calculation of the nutritive value of maize flour, ragi (finger millet) flour and gram flour [8]. Proximate principles of soy protein isolate were determined using A.O.A.C. approved methods [9]. A cereal and pulses mixture were combined and then moistened with up to 10% water of the total flour weight. The resulting moistened flour blend was then passed through a sieve twice to eliminate any coarse or foreign particles that might hinder the extrusion process, ensuring a smooth operation. The flour blend was then placed in low-density polyethylene (LDPE) pouches and preconditioned at room temperature for two hours. Table 1 shows the formulation of Crispies.

Table 1. Formulation of Crispies.

Maize (*Zia mays*) flour %	**Ragi (*Eleusine coracana*) flour %**	**Gram (*Cicer arietinum*) flour %**	**Soy protein isolate (SPI) %**
40	40	5	15

Extrusion process Conditions:

A co-rotating twin screw extruder (Basic Technology Pvt. Ltd., (BTPL lab model) made, model EB-10. Kolkata, India) with three zones i.e., feeding zone, heating zone and die zone, was used to develop the product. The extruder barrel length was 3-feet and diameter 40 mm. It was equipped with a smooth barrel, temperature controllers, variable speed motor and cutter. The operating parameters maintained during manufacture of the Crispies (the final extruded product) are mentioned in Table 2.

Table 2. Operating parameters maintained during manufacture of the Crispies.

Parameters	**Specifications**
Barrel Temperature	110^{O}C
Extruder screw speed	350 rpm
Feeder speed	12 rpm
Cutter speed	2629 rpm
Torque	10.68
Diameter of the die	3 mm

Extrudates (Crispies) were collected and immediately air-dried at 100°C for 30 minutes into a hot air oven to eliminate any excess moisture. The process flow diagram for the preparation of the feed material and extrusion for the preparation of crispies is mentioned in Figure 1, and the Extruded product-Crispies is as shown in Figure 2.

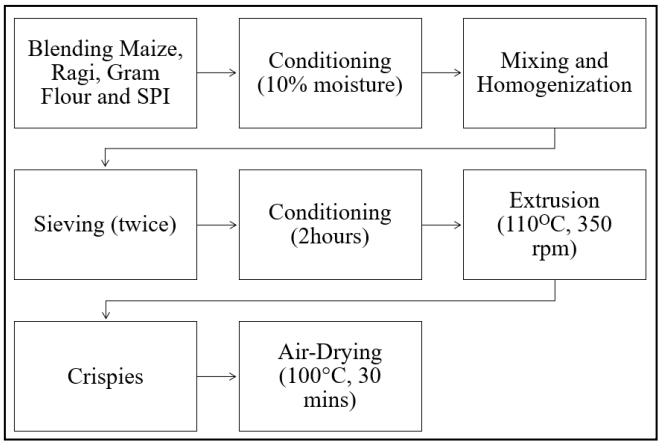

Figure 1. Procedure for Preparation of Crispies.

Figure 2. Crispies

Storage of the Extrudates:

The Crispies were stored in the food-grade Ziplock bags and airtight containers at room temperature for further analysis and utilization in the making of protein-energy bars.

Determination of Proximate Principles:

The nutritional and energy values of the developed Crispies were calculated using Indian Food Composition Tables [10]. The results were converted into 100 g of final product. Soy protein isolate was chemically tested to determine its proximate components. Soy Protein Isolate yields 392 Kcal of energy, 90 g% of protein, 1 g% of carbohydrates (by difference), 3 g% of crude fat, 2 g% of moisture, and 3 g% of ash. The final extrudate was analysed for its chemical composition. Moisture, crude protein, fat, crude fibre, and total ash were determined using A.O.A.C. approved methods, 21st Edn., 2019 [9]. Energy was expressed in terms of kcal was measures as per Food Labeling- Requirements for FDA regulated products. Differences in nutritional levels were used to calculate carbohydrate content. 12% of the Crispies were utilised as raw materials in the standardization of formula for Protein-Energy Bars with an optimised recipe that included Crispies as a variable. The calculated and analytical values of the Crispies were compared using Microsoft Excel (Office 365).

RESULTS AND DISCUSSION

The objective of the research was to produce a raw material in an extruded form, known as "Crispies". The aim was to utilize this material for creating protein-energy bars with an optimized formula that are suitable for athletes and individuals who engage in physically demanding activities. To achieve this, a formulation was developed for "Crispies" by combining maize flour, ragi flour, gram flour, and soy protein isolate as a key ingredient.

Table 1 showing the composition of the ingredients used for the preparation of the extrudate, clearly depicts the cereal to pulses ratio as 4:1. However, SPI used as a pulse protein elevated the protein content of the pulses and thus the cereal protein to pulses protein ratio was found to be 2:5 as per the calculation of the raw materials used. A combination of 4:1 cereals and pulses provides high-quality protein [11]. Yet no studies on the cereal protein to pulse protein ratio for a high protein diet are visible.

In this study, the nutritional composition of Crispies was investigated. The expected nutritional values of Crispies were calculated based on their ingredients and combination. Subsequently, laboratory analyses were carried out to determine the actual nutritional content of the extrudate. The graph in Figure 3 presents the proximate principles of Crispies in both calculated and analytical measurements. The calculated nutritional values were determined using established food composition databases [10]. The analytical values were obtained through laboratory analysis using standard AOAC methods [9].

A comparison was studied between the calculated and analytical values of the proximate principles of Crispies in Microsoft excel (office 365). This comparison may draw attention to the influence of extrusion on the nutritional value of Crispies. Overall, the effects of extrusion on nutritional content vary depending on the food product and the circumstances utilised during the procedure. The graph illustrates the comparison between the calculated and analytical measures in Figure 3. The results showed that there were little differences between the two sets of values.

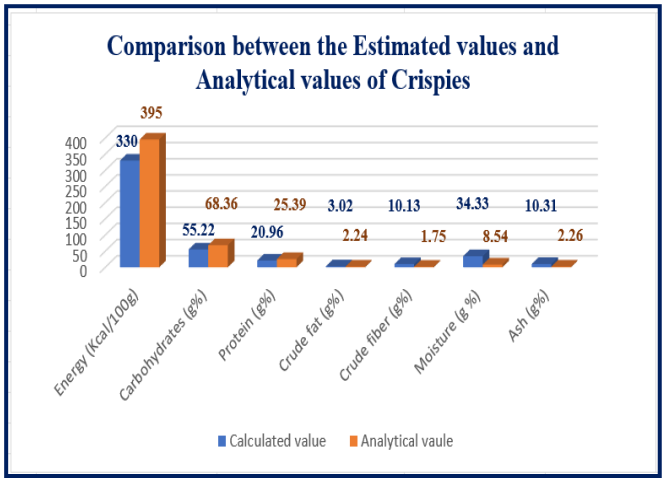

Figure 3. Comparison between the Estimated values and Analytical values of Crispies

Overall, it can be observed that the calculative values for most of the components of the Crispies such as Crude fiber, ash, moisture, and crude fat are higher compared to the analytical values. Whereas Carbohydrates, proteins, and energy score higher in the analytical measurements. By contrast, the analytical values for carbohydrate, protein, and energy are greater by 23.8, 21.1, and 19.7 percent, respectively, than the estimated values. Such trend was also observed in an in vitro test, where extrusion improved protein and starch availability in the researched blends made of extruded maize flour and soy protein concentrates, while maintaining key amino acid levels [12].

However, it was found that the analytical levels of crude fibre crude fat were lower than the calculated values by 82.7 and 25.8 percent respectively. This was also observed in a study carried out on gluten-free snacks based on rice, pea, and carob flours blends where the total dietary fiber was shown to have been reduced by 30% on extrusion [13]. This had been explained in a study on the physicochemical features of soluble dietary fibre from soybean residue, that at temperatures over 100 °C, the dissociation of glycosylated linkages and degradation of the existing polysaccharides lowered the soluble fibre content in the soy hull [14].

Moreover, the ash content reduced by 78 percent after extrusion. Ash content is a measure of its inorganic mineral content, which includes components like calcium, phosphorus, magnesium, and potassium. High temperatures used during the extrusion process, can cause thermal degradation and volatilization of some of these minerals, resulting in a decrease in the total ash content. Also, certain minerals may react with other compounds in the flour blend, resulting in the formation of new compounds or changes in their chemical structure, which may contribute to the apparent drop in ash concentration [15]. Raw ash loss was also evident in a study on extrusion of barley as a feed material [16].

Furthermore, the readings for moisture content depicts that the high temperature treatment of the flour mix during extrusion may have resulted in 75 percent loss of moisture as shown in the comparison between the calculated values of the raw material and the analytical value of the extruded product.

Extruded Crispies ' low moisture content may aid to increase the shelf life of protein-energy bars by lowering the possibility for mould and bacterial development. In addition, a decreased moisture level may aid to keep the Crispies ' texture and crispiness, which can improve the sensory appeal of the protein-energy bars. 12% of the Crispies was incorporated into the protein-energy bar formula, which was optimized to contain above 23g of protein per serving, resulting in a product that meets the criteria for a protein food. The bars were further investigated for their composition, sensory attributes, texture properties, shelf life, and cost-effectiveness.

CONCLUSION

The use of extruded products as a raw material for sports food preparation is a promising approach to developing innovative and nutritious sports nutrition products. Extrusion technology can be used to modify the structure and properties of raw materials, such as proteins, fibres, and carbohydrates, to enhance their nutritional value and functionality. The resulting extruded products have a unique texture, and nutrient composition especially in terms of protein that make them suitable for various applications, including sports food. Moreover, it is important to note that the exact impact of lower moisture content on shelf life will depend on a variety of variables, including protein-energy bar composition, storage circumstances, and packaging. Reduced moisture content of extruded Crispies can contribute to enhancing the shelf life of protein-energy bars because moisture is a critical factor that affects the growth and survival of microorganisms, such as bacteria and fungi, which can cause spoilage and foodborne illnesses, and this may be a beneficial method for enhancing the shelf life of protein-energy bars. In a nutshell, advantages of using extruded grain and pulses as a raw material for sports food include improved nutrient value, better digestion, increased bioavailability, convenience and portability, and flavour, texture flexibility and shelf life.

Future Scope

Extruded grain and pulses have a potential future as a raw material for sports food. Some potential developments and opportunities in this area are:

i. Plant-Based Protein: With a rising need for plant-based protein sources, extruded grains and pulses may give an ideal choice for sports food products. This is especially important for vegetarian and vegan athletes who may have fewer protein alternatives.
ii. Customization and personalization: Extrusion technology may be utilised to develop sports food items that are suited to athletes' demands. This might involve adjusting the protein and carbohydrate content, as well as the flavour and texture, depending on an athlete's nutritional needs and preferences.
iii. Innovation in Formulations: With developments in extrusion technology and ingredient research, there is opportunity for new and inventive sports food product compositions. This might involve the creation of items tailored to certain forms of physical exercise, such as endurance sports or strength training.
iv. Improved shelf life: Extrusion heating may increase food shelf stability by lowering water activity and removing spoiling pathogens.

Conflict of Interest

The authors state that they have no conflicts of interest. The funding agency had no part in the study's design, data collection, analysis, or interpretation, article preparation, or decision to publish the findings.

Author Contributions

Study design: Kanchi Baria, Prof. Komal Chauhan (research guide), Dr. Amit Patel.

Data collection: Kanchi Baria.

Contribution in analysis and tools: Dr. Amit Patel. Dhinal Patel.

Performed the analysis: Kanchi Baria, Dr. Amit Patel, Dhinal Patel.

Paper writing: Kanchi Baria.

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