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EC NUTRITION
Review Article

The Potential of Combining Cereals and Legumes in the Manufacture of Extruded Products for a Healthy Lifestyle

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Received: September 10, 2016; **Published:** September 26, 2016

Abstract

Changes in food consumption preferences have been much discussed in past few years in relation to how consumer lifestyle has triggered an increase in the consumption of ready-to-eat foods. Many of these ready-to-eat food products are high in fat, calories, salt and low in starch, protein and fibre. Cereal and legume seeds can be excellent sources of protein and starch. Legumes, in particular, provide around one-fourth of dietary protein in many countries and are a good source of the essential amino acid lysine. Processing of food has proved to be a useful mechanism to manipulate postprandial protein digestibility and glycemic response food products. The extrusion process is extensively used in the development of snack products. This method involves mixing, forming, texturing and cooking to develop a novel food product. Increasing the popularity nutritionally rich of ready-to-eat products and accessibility of this method captures manufactures attention. This review article focuses on the requirement of starch and protein rich diet to lead a healthy lifestyle and illustrates potential benefit of extrusion method and combination cereal-legume blends in the development of nutritionally rich ready to eat snack.

Keywords: *Extrusion; Starch; Glycaemic Response; Legume*

Introduction

The human diet consisted of unrefined grains and vegetables until the preindustrial era, the food was considerably high in fibre and low in the glycaemic index [1]. In many parts of the world plant-based foods are the primary source of human nutrition as they are rich in carbohydrates, protein and fibers [2]. However, many developed countries have a low intake of whole grain foods in their routine diet and a greater reliance on processed food material. This reliance in high processed foods may have health implications, for instance research has indicated that the use of highly polished rice in bread production results in lower fibre intake in the regular diet, leading to health-related issues [3]. This shift in the food habit of the population in developed countries and fast developing economies has researched in recent years and linked to consumer changes due to its fast changing lifestyle. Many researchers have suggested that this shift will give rise to escalating incidences of health related issues such as diabetes and obesity [4,5]. Consumer's perception towards healthy food habits is increasing in recent years with growing understanding regarding the relation between food composition and its effective nutritional quality of the food [6-8]. This may explain why the emphasis of current research is on the potential of plant originated food sources to be selected for nutrition foods in preference to animal products, for a range of factors including economic returns, ease of digestible protein and starch, and ethical aspects of production [9].

Many national health organizations emphasize the need to improve utilization of nutrients derived from plants owing to their nutri-

tional composition, availability and cost efficiency as compared to animal nutrients. These features may increase the consumer awareness towards plant-based nutrients.

The present paper reviews importance of legumes and cereals as nutrient source. Influence of utilizing legumes and cereals in human nutrition. This article also focused on the nutritional changes occurs in a product during extrusion process.

Importance of Cereals

Cereal based foods remained the predominant diet in the human nutrition for several centuries owing to its macronutrient content which is very vital for human metabolism. In some parts of the world it is still regarded as the prime source of energy (56%) [10]. Cereal consumption provides a significant amount of energy to human body as cereals are a rich source of starch and protein, nearly 50% of the world's cereal production is used for human consumption [11]. Cereals also contain dietary fibre and resistant starch which have been linked to beneficial nutritional profiles such as manipulation of glycaemic control [12,13] and the potential to develop better bowel health [14-17]. In addition, soluble fibers have been shown to produce short chain fatty acids such as propionic acids which are known for their ability to `e cholesterol synthesis [14-17]. Dietary fibre consist of insoluble (lignin) and soluble (arabinoxylan, β-glucan) fibres and these dietary fibres have been shown to affect the rate and degree of starch digestion by forming gelatinous matrices with starch and protein during the human digestion process, which in turn may slow down gastric emptying and further enhance absorption of nutrients from the small intestine [7,11,13,18]. This delay in starch hydrolysis may be responsible for slow release of glucose and in effect lower insulin levels in the bloodstream. The glucose level and insulin level in blood after consumption of food vary with different food items and it is proportionate to amount of glucose consumed. A lower glucose response is considered beneficial for human health [7,11]. Cereal holds mixed linkage β-glucan which classified as dietary fibres which vitiate blood glucose level after consumption of food [18]. Also, cereals contain antioxidants such as phenolic acids which considered as beneficial for human health [19,20]. Many of these phytochemical compounds are prevalent in the outer layers of cereal grains and modern food processing techniques largely remove these compounds thus limiting the nutritional value derived from cereal grains to starch [15,20]. Numerous researchers have studied the relation between cereal intake and the risk of diseases such as cancer, obesity, type 2 diabetes, and cardiovascular disease [7,13,16]. The antioxidant capacity of phenolic compounds present in cereal seeds reduces risk of such diseases [21].

The three most widely consumed cereal grains are wheat, rice and maize. Wheat is one of the most consumed cereals in the world with more than 30% of all wheat produced being consumed in Europe in 2009 due to the dietary requirements of Europe being driven by carbohydrates based foods [22]. Rice is widely accepted as a food product and is consumed as a grain form as well in flour form. Maize has been commercially used to produce breakfast snacks [9]. The importance of ready to eat snack products, such as breakfast cereals, developed by using cereals has been discussed previously by some researchers due to its ease of development and health benefits [7,23,24]. However, many of these food products are made from refined grain flour and therefore are rich in starch and low in the other phytochemical compounds in cereal grains [24].

The effect of starch hydrolysis on glucose response

Starches are hydrolyzed by intestinal enzymes such as α-amylase, glucoamylase and sucrose to produce glucose. Some starch molecules are more easily digested than others and it these readily digestible carbohydrates which depolymerized by the body into glucose which then absorbed through blood system and used as energy. The glycaemic impact refers to the amount of glucose produced after consuming starch-based food. In recent years, there has been much attention given to the roles of the glycaemic impact of foods on obesity and diabetes with high glycaemic impact foods being regarded as responsible for excess energy consumption and hence weight gain, obesity and prevalence of diabetes [7,13,24]. Many researchers have illustrated that it is possible to manipulate the breakdown of starch in cereal based products by altering the product structure, as well as the composition (such as increasing the amount of dietary fibre) and hence reducing the amount of starch digestion occurring during intestinal breakdown of foods [13,16,24]. Foods which have a reduced

starch hydrolysis are referred to as having a low glycaemic impact and may play a vital role in decreasing blood glucose and also helps in maintaining insulin response after diet [7]. Some studies reported that slowing down starch digestion in the small intestine is beneficial for good health, it is likely to reduce entry of glucose into the blood which will help in maintaining blood glucose level and hence reduce insulin requirement of the body, this mechanism plays a vital role in lowering the risk of type 2 diabetes [3]. However not all of the starch is digested in the small intestine, some starch became resistant to digestion and transferred through the gastrointestinal track that portion is called as "Resistant Starch". Which is fermented in colon [14,25-27].

The role of protein in human nutrition

Protein is a primary source of amino acids in our diet and is essential for the building blocks of muscle structure [28]. The requirement of protein varies according to age, for example, between the age of 1-3 years' protein is required at 0.87g/kg/day, where between the age of 9-13 years this requirement is 0.76g/kg/day and for adults after the age of 18 years it should be 0.66g/kg/day. The maintenance of protein content is important in relation to the function of tissues and organs for example kidneys, heart, liver, skin and brain [29]. It is a basic requirement to consume sufficient dietary protein for the synthesis and maintenance of mass and muscle function as protein provides amino acids required to synthesize all proteins in body as well as tissue growth. Global protein requirement is raising attention is past few years. Currently over 900 million of the world's population is malnourished, in fact researchers have estimated that half of the child population suffering with protein energy malnourishment which resulting in growth retardation in Asia and Africa [30]. The essential amino acids determine the quality of food protein and legume protein is rich in essential amino acids such as lysine, leucine and arginine which helps in living healthy lifestyle [31,32]. Whilst cereals contain between 8-12 % protein, the balance of protein is not complete as some amino acids are lacking. This is one of the reasons why researchers have been investigating mechanisms to improve the protein quality and also quantity in cereal based foods, mainly by the use of legume material [10]. For instance, the incorporation of legumes into extruded snack products has been shown to be effective in increasing overall protein content of these starch based food products [10,33-35].

Importance of legumes in developing novel food products

Legumes such as lentils, chickpea and peas could therefore be a major source of protein to a large segment of world's population, especially when supplementing cereal based diets. Legume protein has several advantages over animal protein production, primarily in terms of the overall cost efficiency of producing protein from legumes and the negative effect meat production has on aspects of land production and environmental stability [35,36].

Legume grains contain approximately 20-30% protein, although this may vary according to species and cultivar [36]. Legume protein has several health benefits as they are a rich source of essential amino acids such as lysine, and are relatively low in Sulphur containing amino acids such as cysteine, methionine and tryptophan [35,36]. Albumin and globulin are major storage protein found in legumes about 70% legume proteins are produced by globulins which soluble in salt water. The major globulin found in legumes are leguminin (11S) or vicilin (7S) depending on their sedimentation coefficient [37,38].

Some studies have highlighted the importance of legumes not only as sources of protein but also in terms of their high content of dietary fibre [39,40]. Indeed, most legumes are an excellent source of complex carbohydrates (dietary fibres) with their cell walls containing high molecular weight polysaccharides, often as much as 40% of grain weight, these fibre components can be used as gums and stabilizers in the food industry [18,41]. As mentioned before, these dietary fibre components/complex carbohydrates are useful in human nutrition terms as they can be used to manipulate the rate and extent of starch digestion and hence the postprandial blood glucose response [10,18]. Legumes have been shown to contain significant amounts of slowly digestible and resistant starch [42] and have a protective role in the improvement of gastrointestinal health, glucose tolerance, insulin response and reduction of hypertension [43]. The possibility of using legume grain material in combination with cereal grains is therefore very appealing to the food industry focused on functional healthy foods.

The potential effect of the combination of legume and cereal grains in extruded snack products

Since a diet consisting of purely cereal based food products is not complete in terms of the nutritional profile of proteins, and is also energy dense in terms of readily digestible carbohydrates, legume/cereal combinations in food products are gaining popularity. Some studies have shown the importance of processing (cooking, fermentation and germination) and combining legume with cereals to generate novel food products to increase the nutritional quality [44]. In addition, other researchers have identified that the production of nutritious snack product is possible by blending protein sources (peas, Lentils) with starch sources (wheat, barley and rice) [31,32]. For instance, Tiwari., *et al*. [45] developed protein rich biscuits by adding different levels (5%, 10%, 15%, 20%, 25%) of pigeon pea flour to traditional wheat flour, and other researchers have studied legume supplementation into snack foods [46-50]. In these studies, the results proved an increase in protein content and quality were possible using a strategy of combining grain material. Moreover, Anton., *et al*. [39] showed that the composition of navy and red bean flours to corn starch increased protein and starch content of product with significant reduction of anti-nutrients. Madhumitha and Prabhasankar [51] improved the functional (cooking properties) and nutritional value (protein content and potential digestibility) of pasta by the addition of black grams, whereas Balasubramanian [44] used dehulled legumes in sorghum and wheat based extrudates in the production of high energy produce rich in protein and also high in dietary fibre content. These research findings illustrate that with careful selection of food processing techniques it is possible to change the nutritional profile of starch based (energy dense) foods into one of a more balanced nutritional value.

Cooking soaking, fermentation and extrusion are the commonly implemented processing techniques. These methods help in increasing nutritional of nutrients of the prepared food [10]. Processing also reported to reduce anti-nutritional compounds present in raw seeds. Interaction of heat reduces trypsin inhibitors from the food products. Dehulling helps in reducing tannin content and increasing protein digestibility [10]. Also, processing methods such as soaking seeds before cooking can reduce the cooking time of the food [27,51]. Extrusion is one of the commonly adopted processing technique by food industries which employs mixing, forming, texturing and cooking to develop a novel food product [52,53]. Increasing popularity of ready-to-eat products and accessibility of this method captures manufacturers attention. Extrusion method has wide scope in developing various food products such as cereal-based snacks, ready-to-eat breakfast cereal [6,11,13]. Extrusion is a continuous process involves high temperature, short time where product developed by incorporation of pressure, moisture and temperature to concluding in molecular conversion. These features make extrusion process a versatile processing technique in food product development [54].

Recent research has illustrated that extrusion cooking plays an important role in restricting presence of such anti-nutritional compounds, the mechanical and chemical process leads to increase in protein digestion by denaturation protein structures [10]. Additionally, extrusion process can be useful in lysine retention of cereal-based snacks, increasing screw speed and decreasing the die diameter helps in upgrading lysine maintenance [54].

However, extrusion cooking has been shown to increase the amount of readily digestible starch in food products, and, by increasing the ease of starch hydrolysis, increasing the glycaemic impact of food materials [67,13,47]. This is in the main due to both the thermal and mechanical energy used in extrusion cooking depolymerising starch granules into simple glucose chains and thence allowing our starch degrading enzyme greater opportunity to hydrolyze the starch components [13,19,47,55]. One way of minimizing the effect of extrusion processing on the glycaemic impact of foods has been by the addition of dietary fibres and legumes material. The use of dietary fibre in food production converts the food structure and reduces the starch degradation as well [12,13]. Brennan., *et al*. [13] have also reported the impact of non-starch polysaccharides such as guar gum and wheat bran in preparation of extruded breakfast cereals with results showing a significant reduction in carbohydrate digestion and hence the glycaemic response of pasta. Additionally, some studies reported that inclusion of dietary fibre (pea fibre, guar gum and locust bean) reduces the glycaemic index of pasta by 40% [6,7].

The effect of extrusion parameters on legume proteins have been examined by many authors recently. For instance, Yagci and Evei [15] illustrated that by extrusion like processing the protein and starch digestibility, as well as the antioxidant activity of the food products, could be significantly improved in chickpea and wheat blends. The mechanism of improving protein digestibility has been linked to protein reorganisation during extrusion and research by Osen., *et al*. [48] evidenced the degradation of pea proteins during extrusion and the resulting formation of peptide bonds through covalent bonding. Amongst the many legume plants which may provide sources of protein and fibre to enhance the nutritional profile of extruded cereal products, Lupin has received much attention due to its high protein content, high dietary fibre composition and low fat content [35]. Similarly, faba beans, sword beans, and soya bean have also been used as ingredients to fortify cereal based food products [34,56]. All these studies have pointed to the potential utilization of legumes to alleviate protein energy malnutrition, a subject concisely reviewed by Temba., *et al*. [33].

Conclusion

Currently health and nutrition is a subject which is attracting much attention in both the food science and human nutrition scientific literature. The functionality of starch and proteins is important in relation to technological and dietary understandings in developing novel functional foods. There exists a possibility of utilizing the starch components derived from cereal grains and the protein and dietary fibre components from legumes to create a healthy, nutritious food for consumers. The extrusion process has a potential in generating these quality snack products by combining legume and cereals blends into food items aimed at the discerning consumer.

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Volume 5 Issue 2 September 2016