Using Pulses in Baked Products

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Pulses—thanks to both nutritional and health-promoting features, together with their low environmental impact—satisfy the demand for high-protein/high-fiber products. However, their consumption is still somewhat limited in Western countries, due to the presence of antinutrient compounds including phytic acid, trypsin inhibitors, and some undigested oligosaccharides, which are responsible for digestive discomfort. Another limitation of eating pulses regularly is their relatively long preparation time. One way to increase the consumption of pulses is to use them as an ingredient in food formulations, such as bread and other baked products.

Keywords: pulses ; bread ; bio-technological processing ; air classification ; fermentation ; germination

1. Introduction

Legumes or pulses are dry edible seeds of plants belonging to the Fabaceae (*Leguminoseae*) family, which include field peas, dry beans, lentils, chickpeas and faba beans. The contemporary definition of pulses excludes oilseed legumes and legumes consumed in immature form [1]. Egypt and India consume the largest quantity of pulses; in these regions, pulses play a key role in helping the population to consume suitable levels of several important nutrients, particularly proteins, while in developed countries protein intake is mainly due to the consumption of animal-derived proteins [2]. In Europe, 60% of pulses are consumed in Spain, France, and the UK. It is also important to consider that the way pulses are prepared varies depending on world regions [3]. Nonetheless, pulses are traditionally consumed whole or split after soaking and cooking, although recently they have become increasingly popular and are widely used in food products such as pasta, bread, and other bakery products [4]. Indeed, legumes or pulses represent one of the possible ways to help solve global food security challenges. Indeed, as an inexpensive, sustainable source of proteins and other key nutrients, pulses meet the nutrition and food security requirements of the global population and can support the creation of sustainable and stable agricultural production systems, which could limit the negative effects due to climate change. In this context, the year 2016 was designated by the United Nations as the International Year of Pulses. The purpose of this initiative was to increase public awareness of the nutritional benefits of pulses and their potential role in improving global food security. Three years later, the impact of the International Year of Pulses is still making itself felt.

Pulses are mainly consumed as a whole, but Western countries are increasingly using pulse flour in food preparations for the general population or followers of special diets such as vegetarian, vegan or gluten-free. However, the consumption of pulses is limited due to the presence of antinutrients such as phytic acid, trypsin inhibitors and some non-digestible oligosaccharides that are related, for example, to digestive discomfort [5]. Moreover, the presence of off-flavors discourages the consumption of pulses for some [6].

2. Agronomic, Compositional, and Nutritional Benefits

The awareness and demand for pulses is still growing, and new pulse-containing products are launched on the market every year to meet the demand for products that are gluten-free, high in proteins and fiber, with a low glycemic index and a clean label. Moreover, end-use applications of pulses have generated research interest in many disciplines, such as breeding, genetics, agronomics, health and nutrition. An overview of the scientific literature of the last ten years setting ‘legumes’ or ‘pulses’ as a search term, resulted in the identification of about 1934 scientific papers in the area of Food Science and Technology (source: Web of Science; 2009–2019; updated to 4 July 2019). Taking into consideration all the pertinent research disciplines, more than 700 review papers have been published on pulses in the last five years. A tentative classification of the reviews published in the last two years according to their particular research area is summarized in Table 1; most concern plant science and agronomy (43%), while others (15%) are dedicated to the development of food products, including bread, pasta, snacks and cookies, enriched with pulses to improve their nutritional properties. Finally, the nutritional properties and the health benefits of pulses are the focus of about 10% of the total reviews.

Table 1. Topics of the main reviews published on pulses (source: Food Science and Technology Abstracts; 2018–2019; updated to 03 July 2019).

Research Area	Topic	Reference
Plant science/agronomy	Breeding	Pratap et al. [7]; Morris et al. [8]; Warsam et al. [9]
	Cultivation	Farooq et al. [10]
Nutrition/Health	Health benefits	Luna-Vita et al. [11]; Harouna et al. [12]; Harsha et al. [13]
	Bioactive compounds	Awika et al. [14]; Chhikara et al. [15]; Yi-Shen et al. [16]
	Allergens	Cabanillas et al. [17]
	Anti-nutritional factors	Avilés-Gaxiola et al. [18]
	Starch digestibility	Jeong et al. [19]
Processing	Milling	Thakur et al. [20]; Scanlon et al. [21]; Vishwakarma et al. [22]
	Enhancing nutritional properties	Van-der-Poe et al. [23]; Nkhata et al. [24]
	Bread fortification	Boukid et al. [25]; Rehman et al. [26]; Zhong et al. [27]
Functionality	General	Foschia et al. [28]; Jarpa-Parra [29]
	Emulsifiers	Burger et al. [30]; Sharif et al. [31]
	Structure-function relationship	Shevkani et al. [32]; Lam et al. [33]

3. Using Pulses in Baked Products

The growing interest in gluten-free, vegan and vegetarian diets has resulted in an increase in pulse consumption. Flour from pulses is mixed with other grains (with or without gluten) to make bread, biscuits or cookies, and other baked products. The following section will summarize the strengths and weaknesses of pulse-enriched foods in the past ten years.

3.1. Bread

Bread, a traditional and economical product that is easy to prepare and consume, is one of the most popular foods worldwide and is generally prepared from common wheat. Thus, it is a source of calories and of complex carbohydrates, with a modest amount of essential amino acids such as lysine and threonine. Using refined white flour instead of wholemeal flour, however, reduces the nutritional density and fiber content of white bread [34]. Nowadays consumers are more health oriented and conscious of the environmental and nutritional benefits of food. In response to consumer demands, the food industry is formulating vegetable-based products that fully satisfy the health and cultural concerns of today's typical consumer. From this point of view, pulses are a potential ingredient to improve the quality of products that are already widely consumed. Pulse-enriched wheat flour represents a potential way to increase the nutritional properties of cereal-based foods; it is well known that the amino acid composition of pulses complements that of cereals [35]. They are also rich in bioactive compounds, including fiber [36]. In addition, pulses are characterized by reduced starch bioavailability and high resistant starch content. Most of the studies are focused on reformulating wheat bread, mainly with lentils [37][38], chickpeas [37][39], and peas [37][40]. Protein concentrate and protein isolate from peas, lentils and chickpeas have been successfully incorporated in baked products [37]. However, using concentrated protein leads only to an increase in total protein content, losing the potential health benefits associated with other components present in the flour, including phenolic compounds, fiber, and minerals.

The incorporation of high amount of pulses has been successfully obtained in biscuits, cake, and other chemically leavened products (see section below). On the contrary, it has been a challenge to make bread, because gluten plays a structuring role in bread. On one hand, pulse proteins are not able to form gluten networks, on the other, weak interactions between pulse and wheat proteins reduce the formation of viscoelastic dough and affect air incorporation and gas retention during leavening, resulting in bread with poor crumb structure and texture. Thus, the addition of chickpea or peas flour is limited to percentages below 10–15% [39]. Generally, pulses are incorporated in common wheat flours, as recently reviewed by Boukid et al. [25]. The differences in observations among studies would most likely be due to differences in types of pulses (lentils, chickpea, etc.) and whether the pulses integrated in the formulation constitute dehulled or hulled flour. Unfortunately, most of the studies did not report any details about the type of flour, i.e., whether they were used after dehulling, making the comparison of the outcomes of different studies difficult. The presence of the structural fiber found in dehulled material would influence dough formation and bread performance.

Generally speaking, chickpea replacement of less than 10% creates some difficulties in dough preparation, including increased dough stickiness and reduced dough extensibility [41]. When more than 10% of wheat flour is replaced with fiber from peas, lentils, and chickpeas a significant decrease in water absorption is observed, which could be attributed to the higher amount of fiber present [42]. Moreover, the incorporation of flour from dehulled lentils decreases the time required to form the dough and its stability during mixing, together with its resistance to extension, likely due to gluten dilution [43]. Mixtures of wheat and dehulled lentil flours with 20% inclusion have high protein content but low water absorption, resulting in loaves with extremely reduced volumes and dense crumb structures [43]. Thus, high ratio pulse blends are indicated for different baked products such as biscuits (as described in the following section) or extruded products such as noodles. Blends of up to 15% pulse flour generally result in good loaf volume, firmness, and crumb structure. With increasing pulse levels, loaf volume incrementally decreases, and the color of the crumb darkens due to the Maillard reaction [38][41][43], resulting in a decrease in taste and overall acceptability [40]. Specifically, the best sensorial results in terms of appearance, taste, and color are obtained with the addition of up to 10% pulse flour (specifically peas) for bread, whereas higher proportions lead to a worsening of the product's sensory profile [40]. Finally, the addition of pulses (i.e., chickpeas and peas) has been shown to increase crumb firmness [39][44], likely due to their high amylose content compared to cereals, as mentioned above. The effects of adding pulses on dough rheology and bread quality are reviewed in detail by Boukid et al. [25] and Mohammed et al. [41].

3.2. Other Products

As regards biscuits, reformulation by adding pulses is not as challenging as for bread, since the formation of a gas-retaining gluten network during leavening and baking is not required. Moreover, the increase in hardness associated with pulse enrichment is not such a concern as in bread and could even be positive in cookies.

Cookies consist mainly of flour, sugar, and fat, and therefore the addition of pulse flour could improve their nutritional profile. Researchers have published several studies that show how it is possible to reformulate cookies with the addition of different types of pulses such as chickpeas (up to 10%) [45], lupins (up to 20%) [45], green lentils (from 25 to 100%) [46], and navy beans (up to 30%) [47]. These studies showed that, in cookies, the protein content increased proportionally with the addition of pulse flour while reducing dough spread. Pulse flour incorporation leads to darker surface color and a proportional increase in the hardness of the product. Using pulses to enrich bakery products is particularly suitable for gluten-free formulations, in fact, gluten does not play a key role in cookie-making. Malcomson et al. [48] showed that adding 20% yellow pea flour to gluten-free raw materials such as rice flour and tapioca starch did not modify the characteristics of cookies in terms of acceptability and texture.

In cake-baking, several types of pulse flours can be used as an ingredient, such as chickpeas [49] or peas [50]. Gomez et al. [50] focused on cake volume and observed a substantial decrease in the sample supplemented with pulse proteins;

also, the resultant bubbles were smaller and more uniformly distributed. Firmness increased while springiness and cohesiveness decreased.

Another product that is well suited for reformulation with pulse flour are crackers. Malcomson et al. [48] added 30% of whole green lentil flour to a commercial cracker formulation. His findings show that crackers supplemented with lentil flour results in a protein-rich cracker with twice the total dietary fiber of wheat crackers. Crackers with lentil flour were darker in color, but their crisp texture and peppery flavor were considered acceptable and comparable to the control. Considering the non-essential role of gluten, crackers are suited not only for reformulations but also complete replacement with pulses including chickpea, green, red lentils pinto bean, navy bean, and yellow pea flours. The pulse-based, gluten-free cracker products investigated by Han et al. [51] have proved to be appealing for consumers, thanks to their health benefits. The sensory aspects of this cracker in terms of color, texture and taste were judged positively and were comparable with existing products on the market.

4. Main Barriers to the Use of Pulses and Potential Solutions

Using pulses in food formulations presents some challenges that need to be solved, in view of the nutritional benefits related to their consumption. The first difficulty to be faced is the presence of antinutritional factors, mainly phytic acid and tannins, in the seeds [52], which results in bloating and vomiting after ingestion of raw pulse seeds or flour [53][54]. Nevertheless, the anti-nutritional components may be reduced using different methods such as those recently reviewed by Patterson et al. [55]. The oldest and still widely used method to reduce antinutritional compounds consists of soaking, which leads to a reduction in phytate, which transfers to the soaking water [55].

Another method, dehulling consists of removing the outer layer of seed, which reduces cooking time, removes some antinutritional compounds (e.g., tannins) and improves protein digestibility [56]. Finally, thermal treatments, including extrusion, significantly decrease the presence of antinutritional compounds by eliminating heat-labile antinutrients [57]. Besides antinutritional factors, the sensory profile of pulses—i.e., their beany or bitter flavor profile—which depends on the type of pulses, greatly decrease their acceptability and thus their consumption. Traditionally, fermentation and germination have been used to enhance both the nutritional and sensory profiles of pulses, thanks to the production of aroma compounds and sugars [4].

Finally, incorporating pulses in cereal-based products causes important technological issues. In the case of bread, quality is related to an optimum balance of rheologically important gluten-forming proteins (i.e., gliadins and glutenins) and the addition of pulse flour to the wheat flour matrix leads to variations that inevitably worsen bread quality. The presence of pulse proteins not only dilutes gluten but also causes competition between wheat (gliadin and glutenin) and pulse (albumin and glogulin) proteins. Specifically, pulse proteins have a greater number of hydroxyl groups and for this reason they have a higher capacity for water binding [58]. Pulse fiber has also been reported to compromise gluten–gliadin strand formation [42][59]. Two main approaches can be taken to enhance the quality of final products. One depends on choosing suitable ingredients. The second approach consists of applying (bio)-technological treatments to the raw material.

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