Pulses for bread fortification: A necessity or a choice?

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Abstract:

Background

Pulses are an affordable source of carbohydrates, dietary fiber, vitamins, minerals, phytochemicals, and particularly proteins. These nutritious seeds greatly contribute to food security, sustainable agriculture, biodiversity and environmental changes mitigation. Pulses are, indeed, a protein source with low carbon and water footprints. Interest in the use of pulses and their by-products in bread formulation has been mounting in recent years due to their high nutritional and functional values. Bread is one of the oldest and most consumed food worldwide, but it has an unbalanced amino-acids profile.

Scope and approach

This review aims to provide up-to-date information on the compositional and nutritional attributes of pulses as well as their impact on bread-making quality. Keeping in mind that forthcoming challenges should be overcome to formulate a high-quality bread based on pulses-wheat blends.

Key findings and conclusions

Fortifying bread with pulses will secure a better amino-acids profile and a higher protein intake favoring ensurement of a balanced diet to a wide population with low environmental impact. Hence, pulses consumption is a necessity more than a choice for developing and developed countries with no exception.

Keywords: pulses, legumes, nutrition, fortification, bread.

1. Preface

Legumes belong to the family *Fabaceae* or *Leguminosae* and are important agricultural crops grown all over the world. The term "legume" refers to the plants whose fruit is enclosed in a pod. Legumes are a very large family which consists of 750 genera and 16,000–19,000 species (Ratnayake, Hoover, Shahidi, Perera, & Jane, 2001). Among these, approximately 60 species have been domesticated, including soybeans, mung beans, chickpeas and lentils. Legumes were declared the theme of the year 2016 by FAO (Food and Agricultural Organization of the United Nations) to acknowledge their important contribution in feeding the world. Such celebration aimed to highlight benefits of these crops for farmers, manufactures and consumers, and to promote their growth and implementation in the diet. After cereals, legumes production ranks the second major agricultural sector worldwide, with peas, chickpeas, lentils, and beans being the most consumed (over 70%) of legumes worldwide (FAO, 2015). Legumes are considered "superfood" for their dense nutritional composition providing a multitude of health benefits due to their good supply of micro - and macronutrients. Also, they are cultivated worldwide covering important geographical area, subsequently, they have an important socio-economic impact on developed and developing countries. Such crops are also characterized by low water and fertilizing requirements, high resistant to diseases and important adaptability to harsh conditions (Brueck & Lammel, 2016). Also, intercropping cereals with pulses greatly contributes in the sustainability of crops systems and soil biodiversity as renewable natural resources (Maikhuri, Dangwal, Negi, & Rawat, 2016).

In recent years, great interest was attributed to pulses, "the dry seed of legumes", as a main ingredient or as a fortifying agent for bread. Bread is one of the most consumed products worldwide, it is made from wheat flour, salt and water, with or without leavening agent (*Saccharomyces cerevisiae or/and* sourdough). Although bread provides carbohydrates and energy, it lacks some essential amino acids and bioactive components. Therefore, fortifying wheat flour with pulses might enhance the protein profile as well as the bioactive content of bread. This review aims to raise awareness toward the spectrum of benefits related to the consumption of pulses as well as to the effects of the implementation of the most widespread pulses' species into bread recipe on product's nutritional attribute and quality.

2. Importance of pulses

Pulses, also called grain-legumes, belong to the *Fabaceae* (Figure 1), which are grown primarily for their edible seeds. Pulses belong to the legume family, but the term "pulse" is reserved to the dried seed, according to FAO (2016). The most common pulses are dried peas, beans, lentils and chickpeas. Regardless of the geographical regions, pulses are widely cultivated (Table 1).

The global contribution of legumes, particularly pulses, to a balanced and sustainable humans-environment relation is summarized in Figure 2. Most plants in this family obtain their own nitrogen through a symbiotic relationship with soil microbiome (Daubech et al., 2017), and, thanks to their ability to fixe atmospheric nitrogen in the soil, they reduce the need for nitrogen fertilizers (Couëdel, Alletto, Tribouillois, & Justes, 2018; Moyano, Marco, Knopoff, Torres, & Turner, 2017). Pulses are, consequently, a sustainable production, play an important role in fostering soil fertility, and might be of great importance for farmers with no or limited access to nitrogen fertilizers (Maikhuri et al., 2016). Pulse crops also contribute in mitigating environmental climate changes through reducing carbon and water footprints. Carbon footprints is associated with intensive use of inorganic N fertilizers, responsible for half of all agricultural greenhouse gas emissions (Crews & Peoples, 2004). Durum wheat produced in a pulse-pulse-durum rotation system was shown to have lower carbon footprint (-34 %) than when it was preceded by 2 seasons of cereal crops (Liu et al., 2016). Inter-cropping cereals crops with pulses also increased the biomass, yield stability and protein content of the harvest (Kermah et al., 2017; Naudin, Corre-Hellou, Pineau, Crozat, & Jeuffroy, 2010; Zhang et al., 2015). Pulses also have low water footprint as compared to other sources of protein (e.g. milk, egg and chicken meat) (Mekonnen & Hoekstra, 2010). Therefore, pulses are a 100% renewable energy source to feed humans and animals, as well as maintaining/enhancing the diversification of soil (Brueck & Lammel, 2016; Himanen, Mäkinen, Rimhanen, & Savikko, 2016).

Nutritionally, the consumption of pulses not only brings important variety of micro - and macro-nutrients in the diet, but several evidences underlined their significant health-beneficial properties such as satiety increase (McCrory, Hamaker, Lovejoy, & Eichelsdoerfer, 2010) and cholesterol lowering (Finley et al., 2013; Sagratini et al., 2013; Siah, Wood, Agboola, Konczak, & Blanchard, 2014; Vila-Donat, Fernández-Blanco, Sagratini, Font, & Ruiz, 2015), as well as their action in reducing diet-related chronic diseases including diabetes, metabolic syndrome (e.g. blood pressure and abnormal cholesterol), cardiovascular diseases, and cancer (Dhillon et al., 2016; Feregrino-Pe et al., 2008; Marventano et al., 2017; Messina, 2014; Mollard, Wong, Luhovyy, Cho, & Anderson, 2014; Rebello, Greenway, & Finley, 2014). Pulses also can greatly contribute in the prevention of undernutrition and malnutrition issues in low income countries. Therefore, there has been a continuous increase of interest in pulses integration in foodstuffs-making due to their dense nutritional composition, environmental contribution and technological aptitude. Pulses are consumed either as an intact seed or can be processed before consumption, split or milled, or fractionated to obtain fiber, starch and protein concentrates or isolates (Roy, Boye, & Simpson, 2010). These different ingredients held different physicochemical, nutritional and technological properties that will define their functionality once integrated in food formulation during processing, storage, and consumption.

3. Background information about pulses

3.1. Classification

Table 2 summarizes the main characteristics of the 11 primary pulses, which belong to the *Phaseoleae*, *Cicereae* and *Fabeae* tribes (FAO 2017). Some background information about origin and area of cultivation is shown in Table 3.

3.2. Composition

3.2.1. Nutrients

A massive work has been carried out by FAO to collect information on the nutritional properties of pulses available in the literature. The gathered data were then standardized and included in an open access database online. Table 4 displayed the major macro-components of the most widespread pulses as stated by FAO (2017). The amino acid composition of wheat flour was also included; even though it can be extremely diverse depending on multiple factors, including genetic diversity, effect of processing and environmental conditions similarly to that of pulses.

Pulses can be considered low-energy product, as they provide an amount of energy [an average value relative to Table 4, 318±14 (Kcal/100g), range 301-359 (Kcal/100g)] lower than those of wheat flour (348 Kcal/100g) (Table 4). The highest energy (359 Kcal/100g) is provided by chickpea, Kabuli variety. Carbohydrates content differed vastly among pulses and fluctuated from 10.8% (Adzuki bean) to 51.3% (lupin). Similarly, fat content was quite dissimilar, and ranged from 0.6 g/100 g (Adzuki bean) to 6.5 g/100g (lupin). Pulses are an excellent source of dietary fiber with high range of variability extending from 13.1 g/100g in chickpea, Kabuli to 35.3 g/100g in lupin. For ash content, Pinto bean had the highest value (4.9 g/100g), while lentil showed the lowest one (2.7 g/100g). Notably, according to the FAO (2017) database, important amounts of potassium were found, ranging from 219 to 1940 mg/ 100 g, compared to durum (431 mg/100 g) and common wheat (435 mg/ 100 g) (USDA 2016). Likewise, high calcium content was found (up to 295 mg/100g, Table 4) (FAO 2017). Pulses are primarily known as a valuable source of proteins [from 18.4 g/100g (Bambara nut) to 34.1 g/100g (lentil)] with a balanced amino acids profile, rich in essential amino acids. The amino acids composition of different pulses is shown in Table 5. Lentil contains the highest amount of alanine (1270), followed by moth bean (1200 mg/100 g), while wheat flour was the poorest (543 mg/100 g). Lupin had the highest concentration of most amino acids (Arg, Asp, Glu, Gly, His, Ile, Leu, Phe, Pro, Ser, Thr, Tyr and Val), while Cys, was slightly higher in chickpea desi (646 mg/100 g) than lupin (610 mg/100 g). Similarly, Lys was high in lentil (1710 mg/100 g), followed by kidney bean (1670 mg/100 g) and lupin (1650 mg/100 g) suggesting that these pulses are an excellent ingredient to be combined in wheat-based flour blends to obtain a balanced and complete amino acids profile. Pulses amino acids composition is characterized by a rich Lys content compared to that of wheat flour (416 mg/100 g, Table 5) (Tuśnio and others 2017). Met and Trp were quite low in pulses ranging from 166 mg/ 100 g (Board bean) to 405 mg/ 100 g (Cowpea) and from 115 mg/100 g (Bambara nut) to 328 mg/100 g (Kidney bean). However, wheat flour showed intermediate contents of Met (251 mg/ 100 g) and Trp (130 mg/ 100 g) but high amounts of proline (1594 mg/ 100 g) and Glu (4839 mg/ 100 g). Moreover, pulses have interesting phenolic acids (e.g. folic acid and hydroxycinnaminic acid), vitamin (e.g. ascorbic acid, and vitamin E, B6, B12 and K) and flavonoids (e.g. glycosides, anthocyanins, proanthocyanidins, and isoflavones) (Boschin & Arnoldi, 2011; Boschin, Scigliuolo, Resta, & Arnoldi, 2014b, 2014a; Heiras-Palazuelos et al., 2013). Hence, for consumers and food manufacturers concerned with health and balanced-diet, pulses are naturally rich in a spectrum of bioactive components and are, therefore, a valuable item to be integrated in foodstuff-making. Nevertheless, it should be taken into consideration the presence of some antinutrients in pulses.

3.2.2. Anti-nutrients

Pulses have a dense-nutrient composition but, at the same time, they contain antinutritional compounds, which can negatively affect bioavailability of nutrients and digestibility (Amalraj & Pius, 2015; Moktan & Ojha, 2016), as well as impart bitter or unacceptable taste (Rizzello, Verni, Bordignon, Gramaglia, & Gobbetti, 2017). Antinutrients can be classified in different categories. They can be grouped according to their chemical nature whether proteins (e.g. including lectins, agglutinins, trypsin and chymotrypsin and amylase inhibitors) or non-proteins (e.g. phytic acid, phenolic compounds and saponins) (Dueñas et al., 2016; Martín-Cabrejas et al., 2009). The classification reported in Table 6 was based on antinutrients sensibility to heat treatment since, in some cases, a simple heat treatment may remove the negative effects associated with pulse consumption. Anti-nutrients can be either thermolabile (e.g. protease inhibitors and lectins), or thermostable (e.g. phytic acid, raffinose, tannins and saponins) (Dueñas et al., 2016; Martín-Cabrejas et al., 2009). The presence of high concentrations of trypsin and protease inhibitors reduces the activity of enzymes such as trypsinase, chymotrypsinase, amylase, and lipase (Sathya & Siddhuraju, 2015). Phytic acid inhibitors and lectin may also hamper protein availability and digestibility (Adenekan, Fadimu, Odunmbaku, & Oke, 2018; R. K. Gupta, Gangoliya, & Singh, 2015; Jin et al., 2017; Ohizua et al., 2017). Tannins negatively interfered with the bioavailability of iron (Prasad & Singh, 2015; Sotelo, González-Osnaya, Sánchez-Chinchillas, & Trejo, 2010). Oligosaccharides such as raffinose are responsible for flatulence, bloating and gas formation in the guts (Adeyemo & Onilude, 2013; Winham & Hutchins, 2011). Saponins might be involved in intestinal wall damaging (R. K. Gupta et al., 2015; Prasad & Singh, 2015), while oxalate is reported to be culprit in limiting calcium absorption (Massey & Kynast-Gales, 2001). Considering that pulses are consumed after cooking, antinutrients levels may be decreased or completely hindered. Therefore, processing is needed because these undesirable effects are more correlated to the consumption of raw pulses. Table 6 underlined also some health-beneficial potential of some anti-nutrients. The positive/negative effect on the human health is strictly related to the (i) amount of pulsed consumed, (ii) type of food processing that pulses undergo, and (iii) to individual sensibility.

4. Pulses: a valuable ingredient for bread fortification

Bread is a basic food item that is consumed in variable forms throughout the world. Fortifying a widely consumed food product like bread can, definitely, exert a positive significant impact in term of plant-protein consumption that in turn could contribute to the reduction of water and carbon-foot print associated with the animal-protein consumption (meat/dairy). In a recent report of the International Association of Plant Bakers, ("AIBI Bread Market Report 2013," 2015), bread average consumption in Europe is about 59 kg/person/year, yet different trends are observed across European countries [e.g. Turkey (104 kg) and Bulgaria (95 kg), UK (32 kg). A stable consumption was recorded in several countries (e.g. Finland, Greece and Germany markets), but in others it is slightly decreasing (e.g. Turkey and Ukraine). Per capita consumption in US is around 39.3, but lower values were recorded in Asian countries [e.g. Japan (22kg) and China (5.8kg)].

Towards product innovation and given the increasing awareness to health-beneficial trends of the consumers, bread industry is being driven to bread fortification to enhance its quality through the use of natural ingredients with dense-nutrient composition. In this light, pulses might be considered a valuable fortifying agent for increasing the nutritional value of cereal-based foodstuffs, such as bread, due to their well-balanced amino acid composition and fiber content (Gómez, Oliete, Rosell, Pando, & Fernández, 2008). Pulses might be integrated in bread formula in different forms: dehulled or hulled flour, hydrolysates or protein isolates, germinated or fermented flour, and single or as multi-pulses blends. The addition of pulses to wheat flour based-bread impact nutritional, chemical, physical and functional properties. The resulting blends-based breads have increased the protein, fat, dietary fiber and mineral contents compared to 100% wheat flour based-bread (Indrani, Swetha, Soumya, Rajiv, & Venkateswara Rao, 2011). Functional properties of pulses are well documented (Adebiyi & Aluko, 2011; Aluko, Mofolasayo, & Watts, 2009; M. B. Barac, Pesic, Stanojevic, Kostic, & Bivolarevic, 2015; M. Barac et al., 2010; Hou & Zhao, 2011; Karaca, Low, & Nickerson, 2011). Indeed, pulses flours are recognized for their high water holding capacity, solubility, emulsifying, foaming and gelling properties and emulsifying properties (Adebiyi & Aluko, 2011; Aluko et al., 2009; M. Barac et al., 2010; Barac et al., 2015; Foschia, Horstmann, Arendt, & Zannini, 2017; Hou & Zhao, 2011; Karaca et al., 2011). These properties greatly impacted the rheological properties of the dough.

4.1. Bread made with blends of wheat and pulses

4.1.1. A brief overview on some pre-treatments of pulses

Prior to consumption, pulses might be subjected to preparation step including dehulling, soaking, cooking and extrusion. Pulses out-layers are rich in antinutrients, which might confer a bitter taste or a foaming ability (Stantiall, Dale, Calizo, & Serventi, 2017). Through the removal of the hulls from the rest of the pulses grain, dehulling improves appearance, texture, cooking quality, palatability and digestibility of grain legumes (Egounlety & Aworh, 2003). However, dietary fiber content decreases due to a decrease in insoluble dietary fiber content, and therefore protein and starch contents increase (M. Ma, Wang, Wang, Jane, & Du, 2017; Sakhare & Inamdar, 2014). Likewise, soaking reduced the total amount of saponins in chickpeas and faba beans (8 and 35%, respectively) (Barakat, Reim, & Rohn, 2015). The reduction of saponins can contribute in the improvement of sensory attributes of pulses (e.g. color, odor and taste) thereby increasing their acceptability by consumers (Aremu and others 2016). Cooking methods (boiling, roasting, microwaving, autoclaving and steaming) showed great efficiency in reducing/inactivating the heat-labile antinutrients. Cooked pulses had drop-in tannin, trypsin inhibitor activity and raffinose to negligible concentrations compared to those untreated (T. M. H. Hefnawy, El-Shourbagy, & Ramadan, 2012; M. Ma et al., 2017; Martín-Cabrejas et al., 2009). Boiling resulted in decreased trypsin inhibitor activity (-95%), tannins (-36%) and phytic acid (-42%) (Aremu, Ibrahim, & Ekanem, 2016). These treatments also decreased oxidative enzymes activities that might alternate some nutrients content (María Celia Alasino et al., 2008). Steaming also was effective in retaining the integrity, appearance and texture of the cooked pulses, as well shortening process time (Xu & Chang, 2008). Cooking also influenced the functional properties of on pigeon pea, dolichos bean and jack bean flours, as it increased water absorption capacity (73–96%), decreased protein solubility (>80%) and the tendency to retrogradation of amylose (69–85%) (Acevedo, Thompson, González Foutel, Chaves, & Avanza, 2017). In turn, cooking might induce considerable losses in some bioactive components due to their leaching to the cooking medium or denaturation by the high temperature (Siah et al., 2014). Roasting enhanced fat binding capacity, water holding capacity, gelling capacity, and *in vitro* protein digestibility (Khattab, Arntfield, & Nyachoti, 2009; M. Ma et al., 2017). Microwaving also improved the nutritional quality (i.e. *in vitro* protein digestibility) of pulses (Hefnawy, 2011; Khattab et al., 2009). Compared to soaking, microwaving had less efficiency in reducing tannins, phytic acid and trypsin. Extruding pulses resulted in an important decrease in trypsin inhibitor, phytate and total tannin was reported (Adamidou, Nengas, Grigorakis, Nikolopoulou, & Jauncey, 2011; Alonso, Oroe, Zabalza, Grant, & Marzo, 2000; Chinma et al., 2016). Extrusion also improved *in vitro* protein digestibility and protein efficiency ratio (Milán-Carrillo et al., 2007).

4.1.2. Single pulse flour

Regardless of pulses type, the substitution of wheat flour with pulses flour significantly improved the nutritional value (Alomari & Abdul-hussain, 2013; Erukainure et al., 2016; S. Ma et al., 2014) increasing bread protein, minerals and fiber contents (Man, Păucean, Muste, & Pop, 2015; Moneim, Sulieman, Sinada, & Ali, 2013).

According to mixolab, the inclusion of Bambara flour resulted in worsening dough consistency, starch gelatinization, amylase activity, and retrogradation, except for stability time (Erukainure et al., 2016). The addition of chickpea flour (0-30%) also increased the optimal amount of water to make the dough [from 58.8 % (100% wheat flour) to 62.5 % (30 % chickpea flour)] (Angioloni & Collar, 2012). Likewise, dough enriched with increasing levels of lentil and bean flours (10, 20, and 30 %) showed an increase in water absorption capacity (from 58.50 to 74.9 %) and dough development time (from 3.50 min to 5.50 min), and a decrease in dough stability (from 6.67 to 2.30 min) (Kohajdová et al., 2013). The increased water absorption was attributed to the higher water holding capacity of pulses flour, which is associated with increased total protein and pentosan content (Angioloni & Collar, 2012; Collar, Santos, & Rosell, 2007; Mohammed, Ahmed, & Senge, 2014; Moneim et al., 2013). This likely might result in modifying water distribution and dynamics in the dough.

Extensograph results showed that dough resistance decreased gradually from 5% to 15% level of chickpea supplementation, if compared with wheat flour (Moneim et al., 2013). Addition pulses flours (e.g. Bambara groundnut and chickpea) increased total area/energy, resistance to extensibility and dough development time (S. Ma et al., 2014; Mohammed et al., 2014). Stability and extensibility decreased resulting in stiff dough (S. Ma et al., 2014). Otherwise, an addition level of 10 % chickpea flour increased dough stability and resistance as compared to the control. However, beyond 20%, these parameters decreased. The surface of the dough made with 100 % wheat flour or supplemented with 10 % chickpea flour can be described as “normal”, while blends made with higher levels of supplementation (20-30 %) produced a “sticky” dough surface (Mohammed et al., 2014). Also, relevant changes in pasting properties (i.e. peak viscosity and complex modulus) were observed, which are more dependent on flour biopolymers (Angioloni & Collar, 2012). The results of rapid visco-analyzer showed that increasing chickpea flour level increased in pasting temperature (from 62.0 to 66.5 °C) and dough viscosity. Such result might be attributed to chickpea flour' gelling and thickening properties related to fibers and proteins (Angioloni & Collar, 2012).

Regarding bread properties, the addition of lupin or pea flour at 5% level gave similar loaf height and structure of the 100% wheat flour based-bread (María Celia Alasino et al., 2008; Pollard, Stoddard, Popineau, Wrigley, & MacRitchie, 2002). Pea flour substitution at levels of 10 and 15 % negatively affected specific volume (María Celia Alasino et al., 2008) . Otherwise, 10 % pea flour supplementation enhanced loaf weights and both loaf and specific volume, while these later decreased with the addition of 15 % (Ma et al., 2014) and 20 % (Erukainure et al., 2016). Flour substitution by 15 % cowpea flour resulted in decreasing loaf height and loaf volume and increasing loaf (Olapade & Oluwole, 2013). The volume decreased as chickpea flour substitution (30%) increased, which might be explained by the dilution of gluten content or/and possible interactions among fiber components, water and gluten (Man et al., 2015; Olapade & Oluwole, 2013). Color of crust and crumb of pulses-based bread became darker as the level of supplementation increased due to Maillard reaction (Man et al., 2015). Nevertheless, 10 % chickpea flour addition enabled to obtain a bread with color similar to the control (100% wheat flour) (Mohammed et al., 2014). The sensory analysis revealed that 10% addition of pulses flour (e.g. cowpea, chickpea and bambara nut) to bread was more appreciated than bread made with higher supplementation levels (S. Ma et al., 2014; Man et al., 2015; Olapade & Oluwole, 2013). Furthermore, increasing levels of the lentil flour (around 20% to 25%) induced negative effects on sensorial quality of the bread (Previtali et al., 2014).

Although leavened breads are the most studied due to their popularity all over the world, some attention was attributed also to unleavened bread (e.g. flat-bread, steam bread, Thick kmaj and Arabic bread). Flat bread was made with inclusion of different levels (0-20%) of lupin flour (Alomari & Abdul-hussain, 2013): dough properties revealed an increase in water absorption, possibly due the high water-binding capacity of fiber and protein (Güémes-Vera, Peña-Bautista, Jiménez-Martínez, Dávila-Ortiz, & Calderón-Domínguez, 2008; Turnbull, Baxter, & Johnson, 2005). Another type of flat bread (Thick kmaj) was prepared with faba bean flour (5, 10 and 15%). Protein content increased significantly from 13 % in bread made with white flour to 20 % in 15 % faba bean flour supplemented bread, while bread fat content increased from 1.06% to 1.23%. Moreover, sensory analysis results showed that the higher overall acceptability scores were attributed to the control and the 5% replacement level (Ajo, 2013).

4.1.3. Blends of pulses' flours

Indrani, Swetha, Soumya, Rajiv, & Venkateswara Rao (2011) replaced whole-wheat flour with a multigrain mix (chickpea, barley, soya bean and fenugreek seeds) at different levels (0-40 %) to make north Indian parotta. As a result, water absorption increased, while dough stability, resistance, extensibility and viscosity decreased. Baik & Han (2012) also reported that the dough made from cooked or roasted pulses flour was less sticky than that with fermented flour. This likely due to the lower water absorption capability that might be attributed to protein denaturation or/and starch gelatinization. Also, the physical parameters of bread were affected and a reduction in volume, specific volume, and cambering were observed (Baik & Han, 2012). At higher levels (>20 %), the aspect (shape and crust color) and the texture (crumb elasticity and firmness) of breads were negatively impacted (Kohajdová et al., 2013). Sensory evaluation showed that 10% based-bread was the most acceptable (Kohajdová et al., 2013). Furthermore, Baik & Han (2012) observed that roasted flour had a better aroma and loaf volume of bread as compared to flour from cooked legume, indicating the importance of the pretreatment optimization.

4.1.4. Blends of pulses' flours and structuring agents

As previously reported, high level of pulses flours negatively impacted bread texture and volume. Several studies were carried out to find the suitable formulation based on wheat-pulses blends to overcome the drawback of pulses' high substitution level for wheat flour, on technological quality (Man et al., 2015;

Mohammed et al., 2014; Yamsaengsung, Schoenlechner, & Berghofer, 2010). The solution was to rely on the addition of vital gluten or structuring agents, which can mimic gluten properties such as emulsifiers, hydrocolloids and enzymes. Baking performance with wheat flour replaced with 10% with pea flour was improved with the use of 1 % sodium stearoyl lactylate with azodicarbonamide (Alasino, Osella, De La Torre, & Sanchez, 2011). Yamsaengsung et al. (2010) developed two formulations of white and whole wheat flour-based bread using 11% of chickpea and 1.0% emulsifier, without altering the technological quality. Furthermore, Indrani, Swetha, Soumya, Rajiv, & Venkateswara Rao (2011) suggested the use of 3% of a mixture of additives (dry gluten powder, sodium stearoyl-2-lactylate and hydroxypropylmethylcellulose, and their combinations) to compensate the dilution of gluten associated with addition of pulses. This addition enhanced the overall bread quality up to 30 % pulses addition. Later, (Angioloni & Collar, 2012) assayed the addition of gluten (with a range from 1 to 5% of wheat flour) and carboxymethylcellulose (with a range from 1 to 5% of wheat flour), revealing that the combination of 42% of pulse with 6% structuring agents enabled to obtain acceptable breads with high fiber and proteins fractions, and reduced starch hydrolysis and glycemic index (Angioloni & Collar, 2012).

Hydrocolloids were also added to improve organoleptic properties of bread enriched with hydrated and non-hydrated pea flour. As a result, the addition of guar gum (2%) to hydrated pea flour gave bread with comparable overall quality to that of the wheat control. This addition improved dough properties and reduced bread crumb's firmness (Previtali et al., 2014). In another study, fortified-bread (25% lentil flour) showed high acceptability, when 2% of guar seed flour was added to the formulation (Previtali et al., 2014). A mix of enzymes (transglutaminase and glucosidase), emulsifiers (sodium stearoyl-2-lactylate, diacetyl tartaric acid esters of mono and diglycerides, and their combination) and oxidant (ascorbic acid) was assayed to enhance dough and bread supplemented with lupin flour (15%) (Yorgancilar & Bilgiçli, 2014). All additives, except transglutaminase, increased development time and stability of the enriched dough. Combining emulsifiers gave the highest bread volume and the lowest crumb firmness after storage (3 days) (Yorgancilar & Bilgiçli, 2014).

4.2. Blends fortified with pulses' aqueous extracts

Recently, water/salt-soluble extracts were produced from pulses (pea, lentil, and faba bean flours) flours doughs, which were made using proteolytic enzyme preparation (25 g/100 kg of proteins) and *L. plantarum 1A7* as starter for fermentation. Antifungal proteins were identified, in particular nine peptides as sequences encrypted in legume vicilins, lectins and chitinases. Also, aqueous extracts of fermented sourdough (*Lactobacillus brevis* AM7 and *Phaseolus vulgaris* cv. Pinto) was characterized by an antifungal property, probably attributed to the activity of Phaseolin alpha-type precursor, phaseolin, and erythroagglutinating phytohemagglutinin precursor (Coda et al., 2008). These extracts were used as an ingredient for making bread in a pilot plant that resulted to have longer shelf-life than control bread (Rizzello et al., 2017). Indeed, with water-soluble extract (27%, v/w), no fungal contamination was recorded in stored bread (14 days, 25 °C) (Coda et al., 2008; Rizzello et al., 2015, 2017).

4.3. Blends fortified with pulses' protein isolation

4.3.1. Protein isolation

Protein isolation was achieved generally following a wet extraction, which comprises the following phases:

Defatting: The process of protein isolation involves a defatting pretreatment to remove fiber and fat using hexane or petroleum ether (Adamantini Paraskevopoulou, Chrysanthou, & Koutidou, 2012; Peyrano, Speroni, & Avanza, 2016).

Solubilization: Protein separation is generally carried out using an alkaline or acid solution (Boye, Zare, & Pletch, 2010). Defatted flour was solubilized in distilled water (10 g/ 100 mL) and pH was adjusted (alkaline extraction: pH=8-11 using NaOH; acid extraction pH<4 using citric acid) (Pelgrom, Vissers, Boom, & Schutyser, 2013; Peyrano et al., 2016). The mixture was left to stand at the adequate temperature to maximize the solubilization. Proteins can be solubilized using water, salts, methanol, ammonium sulfate, and acetone (Adenekan et al., 2018; Wati, Theppakorn, Benjakul, & Rawdkuen, 2010).

Precipitation: Following centrifugation, the solubilized proteins are precipitated by isoelectric precipitation (isoelectric point (pH 4.8)), ultrafiltration or membrane separation to recover the protein (Papalamprou, Doxastakis, & Kiosseoglou, 2010)

Drying*:* The isolated proteins were dried using a spray-, drum- or freeze-drying method (Johnston, Nickerson, & Low, 2015). Wet extraction enabled the separation of proteins and starch. Fibers also are recovered to be used as a functional ingredient.

4.3.2. Effect of protein isolates/concentrates of bread quality

Besides being highly nutritious, proteins isolates/concentrates have interesting functional properties like solubility, gelation and water binding resulting in significant changes in dough and bread quality (Kiosseoglou & Paraskevopoulou, 2011; Makri, Papalamprou, & Doxastakis, 2005; Mohammed et al., 2014). Nutritionally, the addition of protein isolates/concentrates increased protein amounts particularly essential amino acids (e.g. lysine) (Franco-Miranda, Chel-Guerrero, Gallegos-Tintoré, Castellanos-Ruelas, & Betancur-Ancona, 2017; Mubarak, 2001) and improved *in vitro* protein digestibility (Mubarak, 2001). Regarding rheological properties, dough water absorption increased (Mubarak, 2001), due to proteins high water binding capacity (Turnbull et al., 2005). With respect to the control, the addition of protein hydrolysates (from lima bean or cowpea) decreased tenacity and slightly increased elasticity of the dough (Franco-Miranda et al., 2017). Dough weakening might be explained by the addition of non-gluten proteins inducing a dilution effect of gluten. An increase in stability time was observed followed to a substitution of 5 or 10% isolates of proteins, probably resulting from lupin protein entrapment within the gluten network structure (Paraskevopoulou, Provatidou, Tsotsiou, & Kiosseoglou, 2010). At higher levels (beyond 10 %), dough stability decreased (Mubarak 2001; Serventi et al., 2013). Loaf volume of breads made with proteins isolates (up to 9% level) or concentrate (up to 3% level) was comparable to 100% wheat flour based-bread (Mubarak, 2001). Indeed, pulses' proteins are not as elastic as gluten, so they are unable to form an extendable network and, consequently, bread crumb appeared more compact due to limited cell expansion (Paraskevopoulou, Provatidou, Tsotsiou, & Kiosseoglou, 2010). Beyond 10 %, protein concentrate had detrimental effect on bread textural quality (high firmness and chewiness and low loaf volume) (Mubarak, 2001; Paraskevopoulou et al., 2010; Serventi et al., 2013; Serventi, Vittadini, & Vodovotz, 2018). Indeed, 9 % of chickpea protein concentrate did not show negative effects on bread texture, except of slight increase firmness, possibly because of low fats and saponins (Serventi et al., 2018). As for sensory analysis, no alteration in bread quality was found with addition of proteins isolates (up to 9%) or protein concentrate (up to 6 %) to bread formula (Mubarak, 2001). It was also underlined an anti-staling effect of lupin proteins isolates resulting in delaying bread firming following storage for 24 and 48 h (Paraskevopoulou, Provatidou, Tsotsiou, & Kiosseoglou, 2010). Possibly, an interaction between starch or/and protein might be involved in preserving the moistness by reducing water migration (from the crumb to the crust) or/and amylopectin retrogradation.

4.4. Blends fortified with germinated pulses flours

4.4.1. Pulses germination

Germination is a solvent free, simple, low-cost and green process resulting in nutrient compositional changes, which are often associated with health benefits. In this light, germination of pulses has been intensively investigated as a mean to enhance their nutritional value by increasing contents and availability of nutrients and reducing antinutrients (Acevedo et al., 2017; Benítez et al., 2013; Dueñas et al., 2016). Indeed; during germination, the excessive enzyme actions result in the hydrolysis of starch, protein and lipid (Benítez et al., 2013; Mamilla & Mishra, 2017). Consequently, the nutrient composition of pulses (e.g. horse gram, chickpea, red lentil, mung bean, kidney bean and soybean) changed (by increasing protein, fiber, total polyphenol content, and antioxidant activity, and decreasing fat, ash and carbohydrate) as well as antinutrients (by decreasing tannin, phytate, and oxalate) as compared to non-germinated flour (Mamilla & Mishra, 2017; Moktan & Ojha, 2016). In particular, phenolic acids (+30%) and DPPH (63%) (2,2-diphenyl-1-picrylhydrazyl) scavenging activity were increased in germinating pigeon pea. Likewise, the inhibitory potential of this extract against α-glucosidase was increased after germination (Uchegbu & Ishiwu, 2016). Such results might be attributed to increasing activity of enzymes of biosynthetic nature, which result in high content of bioactive compounds with improved nutritional quality (Benítez et al., 2013; Dueñas et al., 2016; Khalil, 2001; Mamilla & Mishra, 2017). For instance proteinases are activated during germination, which may lead to the release of some bioactive amino acids and peptides (Devi, Kushwaha, & Kumar, 2015). Germination was also an effective strategy of antinutrients mitigation. Indeed, tannins and phytic acid of pulses (e.g. mung beans, pigeon pea, lentil and chickpea) were significantly reduced after germination (Gupta et al., 2015; Ibrahim, Habiba, Shatta, & Embaby, 2002; Khalil, 2001; López-Martínez, Leyva-López, Gutiérrez-Grijalva, & Heredia, 2017; Martín-Cabrejas et al., 2009). Another factor to be taken into consideration is the condition of germination including germination temperature and duration. For instance, a reduction in tannic acid was of 8-23 and 14-27% in chickpea varieties after 24 and 48 hours (El-Adawy, 2002).

4.4.2. Effect of germinated pulses flours on bread quality

The incorporation of germinated pulses flour in bread is recommended for nutritional enrichment (Ertaş, Bilgiçli, Özcan, & Sarı, 2014; Ouazib, Garzon, Zaidi, & Rosell, 2016). Gram horse flour incorporation (6%) in bread enhanced the polyphenol and antioxidant contents while retaining acceptability of a sensory panel (Moktan & Ojha, 2016). Breads supplemented with 10% germinated pulses flours (lupin and chickpea) showed superior technological (volume, specific volume, symmetry and texture) compared to the control sample (100% what flour) (Levent, Bilgiçli, & Ertaş, 2015). Such result might be likely attributed to improving hydrolytic enzymatic activity and soluble components (Ouazib et al., 2016). Beyond 15% addition level of cowpea germinated flour, sticky dough was produced, which caused difficulties for handling. In this case, it could be possible that by adding the germinated flour you are bringing in the dough formulation also proteolytic and amylolitic enzymes compromising the techno-functionality played by gluten and wheat starch in the bread system. Also, the obtained bread had a lower volume and a crumb compact structure (Hallén, Ibanoğlu, & Ainsworth, 2004). Furthermore, 20% addition of chickpea flour showed detrimental effect on bread quality (reduction in volume and increase in crumb firmness) (Ouazib et al., 2016). As for color, yellowness and saturation (C*) was not affected after 10% germinated chickpea flour fortification, while color was worsened in the case of 20% replacement (Ouazib et al., 2016).

4.5. Blends fortified with fermented pulses flour

4.5.1. Pulses fermentation

Fermentation is reported to be safe processing to enhance the nutritional value of pulses (Adeyemo & Onilude, 2013; Bartkiene et al., 2016; Coda et al., 2008; Kapravelou et al., 2015; Osman, 2011; Rizzello, Calasso, Campanella, De Angelis, & Gobbetti, 2014; Xiao, Huang, et al., 2016). Solid state bioconversion is also a microbial bioprocessing, which is a simple alternative technology to improve the nutritional, nutraceutical and palatable properties of legumes and/or cereals (Sánchez-Magaña et al., 2014). A collection of pulses (faba bean; lupine, chickpea; and peas) and their mixture were subjected to solid state fermentation by *Rhizopus oligosporus* (Nassar, Mubarak, & El-Beltagy, 2008). As result, fermentation increased protein and fiber, while decreased fat, ash and carbohydrate contents (Nassar et al., 2008). Solid-state fermentation with *Rhizopus* spp. enhanced isoflavone aglycones, total phenolic content, and antioxidant activity of black soybean (Cheng, Wu, Lin, & Liu, 2013). The product of solid-state black soybean fermentation serves as a functional ingredient for their potential health such as antioxidative and cytotoxic activities (Cheng et al., 2013; Chia et al., 2013). Solid-state fermentation using a mix of fungi (*Aspergillus awamori*, *Aspergillus oryzae*, *Aspergillus sojae*, *Rhizopus azygosporus* and *Rhizopus sp*) enhanced the antioxidant activity, total phenolic and anthocyanin contents of black bean (Lee, Hung, & Chou, 2008). Fermentation using *BCRC 30222, Aspergillus awamori, Actinomucor taiwanensis* and

Rhizopus sp. was reported to increase in total phenolic and antioxidative agents in comparison with the non-fermented soybean (Lin, Wei, & Chou, 2006). Likewise, fermented black soybeans with *Aspergillus awamori* showed higher amino acids and total phenolics than to those non-fermented (Chen, Lee, & Chou, 2011).

Recently, Curiel et al., (2015) assayed the impact of sourdough fermentation with selected lactic acid bacteria (*Lactobacillus plantarum C48* and *Lactobacillus brevis AM7*) on the nutritional and functional properties of some pulses (*Phaseolus vulgaris, Cicer arietinum, Lathyrus sativus, Lens culinaris* and *Pisum sativum* species). Pulses sourdough based-dough had higher free amino acids, soluble fiber, g-aminobutyric acid), total phenols, antioxidant and phytase activities than conventional dough (Curiel et al., 2015). Likewise, fermented soybeans (*Bacillus amyloliquefaciens*, *Lactobacillus* spp., and *Saccharomyces cerevisiae. Bacillus amyloliquefacie or Bacillus subtilis)* had increased antioxidant capacity and scavenging ability (Chen et al., 2011; Juan & Chou, 2010) as compared to the control. Similarly, fermented chickpeas (with *Cordyceps militaris)* had enhanced crude protein and essential amino acids as well as antioxidant and scavenging activities, ABTS radical scavenging activities and reducing power (Curiel et al., 2015; Xiao, Huang, et al., 2016). Fermentation also improved the functional properties of pulses flour such as water absorption index, water holding capacity, fat absorption capacity and emulsifying properties (Xiao et al., 2015). Thus, flour deriving from fermented pulses might be considered of great potential as a functional ingredient for foodstuff-making (Xiao et al., 2014, 2015).

Regarding antinutrients, fermentation reduced stachyose and raffinose (Nassar et al., 2008). For instance, tannin (from 1.93 to 0.12 mg/g) and phytate contents (from 1.16 to 0.04 mg/g), as well as trypsin and protease inhibitors (from 1.20 to 0.010 and 1.2 to 0.020, respectively) were reduced after fermentation by *Lactobacillus plantarum* (Adeyemo & Onilude, 2013). Similar results were obtained after the fermentation of grass pea and soybean with *Lactobacillus plantarum* (Limón et al., 2015; Starzyńska-Janiszewska & Stodolak, 2011; Wang et al., 2010) and spontaneous fermentation of kidney beans (Granito and others 2002). Sourdough fermentation also enabled a up to 64% decrease in raffinose and tannins (Curiel et al., 2015). Besides reducing antinutrients amounts, pulses fermentation (by *Bacillus amyloliquefaciens*, *Lactobacillus* spp., and *Saccharomyces cerevisiae. B. amyloliquefaciens*) reduced allergens (Chi & Cho, 2016). After 24 h of fermentation, trypsin inhibitors and glycinin were reduced by 50% and 58%, respectively (Seo & Cho, 2016).

4.5.2. Effect of fermented pulses flours on bread quality

Fermented pulse flour incorporation in breads formula improved their nutritional value in terms of total dietary fiber, protein digestibility, mineral, amino acid, fat and antioxidant contents of composite breads (Chinma et al., 2016; Rizzello et al., 2014; Xiao et al., 2014; Xiao, Fan, et al., 2016). Furthermore, antinutrients were reduced such as phytate and tannin compared to non-fermented pulses (Chinma et al., 2016; Rizzello et al., 2014; Shrivastava & Chakraborty, 2018; Xiao et al., 2014; Xiao, Fan, et al., 2016). As for bread quality, fermented chickpea flour addition (50g/Kg) enhanced specific volume and crumb firmness than the wheat 100% flour bread, unlike non-fermented flours. Yellowness index was also enhanced due to the naturel yellow pigment of chickpea, but reduced crumb lightness probably because of Maillard reaction' products (Xiao, Fan, et al., 2016). In addition, bread made with fermented flours were more appreciated by the panel in terms of appearance, texture, color and overall acceptance (Xiao, Fan, et al., 2016).

Also, Chinma et al. (2016) studied bread fortified with bambara nut sourdough flour (0, 5, 10 and 15%), and found that up to 10% substitution, bread had better taste, flavor and overall acceptability compared to wheat bread, while color and texture were not affected by the addition (10%). Beyond 15%, the addition of pulses sourdough flour to wheat flour was correlated to dough weakening (Rizzello et al., 2014). As a result, a decrease in specific volume was observed, which might be due to the dilution effect on gluten resulting in less retention of gas (Chinma et al., 2016; Rizzello et al., 2014). At 30%, bread was not acceptable due to the decrease of the volume and crumb cells, while the addition of 15% did not affect the structure (Rizzello et al., 2014). Based on sensory evaluation, Shrivastava & Chakraborty (2018) optimized a bread recipe based on 18% fermented chickpea flour with addition of 2% xanthan gum to compensate gluten dilution.

5. Conclusions and perspectives

Pulses are bio-diverse, highly nutritious and cultivated worldwide. Indeed, pulses are powerful crops to fight undernutrition in low-income regions and malnutrition in high-income regions of the world. Pulses use to be called the “Poor Man's Meat” because they are economically-affordable and highly-nutritional and are nowadays becoming also the “Rich Man’s Meat”. Therefore, fortifying wheat flour with pulses toward developing new healthy food products might be the right trend to follow.

Pulse flour incorporation in bread was carried out mainly to improve the nutritional profile to provide a balanced amino acid profile rich in essential amino acids. In the frame of environmental sustainability of farming, they are also a source of proteins with low carbon and water footprints.

Bread made with blends containing pulses (10-15%) has an improved nutritional composition as well as appreciated technological and sensorial traits. Beyond 15% supplementation, additives incorporation might be a good alternative to compensate the dilution of gluten, thereby maximizing nutritional advantages and overcoming technological flaws. Pulses flour pre-treatment (e.g. germination and fermentation) may provide additional benefits such as increasing nutrients availability and decreasing antinutrients. More rigorous studies, such as full-factorial studies, are needed to assess the effects of processing, additives and their combination on bread quality and to optimize formulations/processes for high-quality pulses based-bread.

Author Contributions

FB collected the data and compiled and wrote the manuscript. EZ, EC and EV planned, drafted and corrected the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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Figure caption

Figure 1: Classification and botanical description of pulses. This figure underlined the major species of pulses belonging to the family of *Faboidae*.

Figure 2: Importance of pulses. This figure highlighted the contribution of pulses to a balanced and sustainable Humans-Environment relation indicating the possible benefits that might be gained from the cultivation of such crop.

Table 1: production quantity and area harvested of pulses versus cereals (FAO 2016).

	Pulses		Cereals	
Area	**Production (tones)**	**Area harvested (Ha)**	**Production (tones)**	**Area harvested (Ha)**
European Union	628153	245041	402085	164234
Low Income Food Deficit Countries	2647118	4553099	5567552	3578558
Net Food Importing Developing Countries	1663486	2238303	5616160	3637773

http://www.fao.org/faostat/en/#data/QC

Table 2: Common name and scientific name of pulses

Common name	Scientific name
	Phaseoleae
Phaseolus	
Common bean	*Phaseolus vulgaris* L.
Lima bean	*Phaseolus lunatus* L.
Vigna	
Mungo bean	*Vigna mungo* L.
Adzuki bean	Vigna angularis Wild.
Mung bean	Vigna radiata L.
Rice bean	*Vigna umbellata* Thunb.
Moth bean	*Vigna aconitifolia* Jacq.
Cowpea	*Vigna unguiculata* L.
Bambara groundnut	*Vigna subterranea* L.
Cajanus	
Pigeon pea	*Cajanus cajan* L.
	Cicereae
Chickpea	*Cicer arietinum* L.
Hyacinth bean	*Lablab purpureus* L.
	Fabeae
Lens	
Lentil	*Lens culinaris* Medik.
Vicia	
Broad bean	*Vicia faba* L.
Vetch	*Vicia sativa*
Pisium	
Pea	*Pisum sativum* L.
	Other dried pulses
Lablab, hyacinth bean	*Lablab purpureus*
Jack bean	*Canavalia ensiformis*
sword bean	*Canavalia gladiata*
Winged bean	*Psophocarpus tetragonolobus*
Velvet bean	*Mucuna pruriens*
Yam bean	*Pachyrhizus erosus*
Grass pea	Lathyrus sativus

Table 3: Background information of pulses.

Species	Characteristics	References
Dry beans	are an important crop worldwide of pulses, which require warm climate to grow.	(Food And Agriculture Organization of the United Nations, 2016).
Dry board beans	are an ancient crop species that originated in the Near East, is mainly grown in Europe, North Africa, the Middle East, and China.	(Li & Yang, 2014).
Dry peas	have been grown commercially in western Europe, mainly as a spring crop.	(Le May, Guibert, Baranger, & Tivoli, 2014).
Chickpea	is a valuable ancient pulse, which grows well in different soils and climates. It is cultivated in the Indian subcontinent, North Africa, the Middle East, Southern Europe, Asia, the Americas and Australia. Desi and kabuli are the most cultivated varieties.	(Thushan Sanjeewa, Wanasundara, Pietrasik, & Shand, 2008).
Dry cowpeas	are among the most popular pulses mentioned throughout Eastern and Southern Africa.	(Keller, Mndiga, & Maass, 2006).
Pigeon peas	also known as red gram, is among the important grain pulses grown and consumed in in south-west Nigeria. It is tolerant to drought and has wide adaptability to different environmental conditions.	(Ohizua et al., 2017).
Lentils	are commonly consumed worldwide, particularly in the Mediterranean area.	(Turfani, Narducci, Durazzo, Galli, & Carcea, 2017).
Bambara beans	are grain indigenous to sub-Saharan Africa. Though an underutilized crop, it is ranked next to cowpea.	(Erukainure et al., 2016).
Lupins	are relatively more tolerant to several abiotic stresses than other pulses, with great potential in poor and contaminated soils reparation.	(Coba de la Peña & Pueyo, 2012).
Vetches	are consumed by humans since the Neolithic Era, but currently they are mainly used as fertilizer or livestock fodder N.	(Food And Agriculture Organization of the United Nations, 2016).
Other minor pulses	• Green gram is one of the important pulse crops cultivated in India since ancient times and it is widely cultivated throughout the Asia. • Faba bean (*Vicia faba* L.) is grown worldwide under different cropping systems, extensively cultivated in West Asia and North African. Faba bean contributes to the sustainability of cropping systems. Faba bean breeding for resistance to different types of diseases including viruses was reviewed. • Grass pea *(Lathyrus sativus* L.) is an annual pulse crop, which belongs to the Fabaceae family and is mostly cultivated for stock-feed and human consumption in Asian countries.	(Rubiales, Rojas-Molina, & Sillero, 2016) (Kumar, Nidhi, Prasad, & Sinha, 2015; Sillero et al., 2010). (Tamburino et al., 2012).

Table 4: Macro-components of mature, whole, dried, raw pulses (expressed per 100 g edible portion on dry matter basis).

Common name	Energy (kcal)	Water (g)	Protein (g)	Carbohydrates (g)	Fiber (g)	Fat (g)	Ash (g)
Bambara groundnuts	325	9	18,4	33,7	28,9	6,4	3,4
Broad bean	309	10,9	25,3	38,3	20,8	1,4	3,3
Adzuki bean	318	11	20,5	51,3	13,1	0,6	3,7
Chickpea, desi	332	10	21,2	40	21,2	5	2,7
Chickpea, kabuli	359	8,5	20,8	48,9	13,1	6,1	2,8
Common bean	305	10,4	20,9	40,7	22,6	1,5	3,8
Cowpea	324	10,6	22,5	46,9	14,6	1,9	3,5
Kidney bean	307	10,9	22,8	39,4	21,7	1,6	3,6
Lentil	324	9,7	24,4	44,8	17	1,5	2,7
Lima bean	316	9,2	20,9	45	19,1	1,5	4,2
Lupin	309	9,4	34,1	10,8	35,3	6,5	3,8
Moth bean	326	9,6	23,9	45,9	14,9	1,9	3,8
Mung bean	325	9,7	20,9	49,6	15,4	1,3	3,1
Mungo bean	316	9,8	23,9	42,2	19,5	1,4	3,4
Pea	310	11,3	23,4	38,4	22,2	2,1	2,7
Pigeon pea	306	11,4	20,6	41	21,4	1,8	3,8
Pinto bean	301	12,4	19,6	43,8	18	1,3	4,9
Wheat flour (control)	341	12.2	12.1	69.4	1.4	1.7	2.7

(Food And Agriculture Organization of the United Nations, 2016) FAO/INFOODS Global Database for Pulses on Dry Matter Basis – version 1.0 (PulsesDM1.0) - 2017

Table 5: Amino acid profile of some pulses (expressed in mg/ 100 g edible portion on dry matter basis).

	Ala	Arg	Asp	Cys	Glu	Gly	His	Ile	Leu	Lys	Met	Phe	Pro	Ser	Thr	Trp	Tyr	Val
Adzuki bean	1190	1320	2430	190	3190	779	540	815	1720	1540	216	1080	900	1000	694	197	609	1050
Bambara groundnuts	856	1270	2130	144	3250	552	394	870	1510	1220	399	946	831	1140	834	115	449	836
Broad bean	1000	2380	2720	303	4240	1050	652	1010	1810	1570	166	1070	1010	1180	870	217	802	1120
Chickpea, desi	922	2170	2370	646	3840	798	600	893	1600	1420	220	1190	1090	1190	773	217	626	908
Chickpea, kabuli	817	1660	2110	267	3900	802	637	817	1470	1220	272	1200	969	1020	831	213	609	824
Common bean	971	1270	2520	104	3380	898	590	760	1480	1300	185	1000	921	1220	881	234	638	961
Cowpea	1050	1580	2540	114	3960	928	766	1040	1760	1510	405	1260	1040	1100	891	253	649	1190
Kidney bean	996	1420	2900	242	3160	1160	602	1110	1970	1670	271	1310	654	1180	1040	328	905	1400
Lentil	1270	1830	3190	229	4710	1020	557	971	1850	1710	200	1110	1210	1100	773	239	694	1220
Lima bean	1070	1280	2700	231	2960	883	639	1100	1800	1400	264	1200	950	1390	903	248	740	1260
Lupin	1120	3610	3380	610	7930	1360	884	1350	2460	1650	215	1330	1350	1640	1160	281	1130	1300
Moth bean	1200	1310	2490	104	3570	965	698	1070	1750	1470	325	1110	1040	1080	924	231	650	1170
Mung bean	1020	1390	2490	161	3750	1440	559	605	1480	1160	224	1010	980	1390	772	208	560	937
Mungo bean	1060	1500	2960	180	4220	952	674	1020	1890	1550	313	1400	1030	1260	757	241	736	1160
Pea	1040	2030	2690	263	4020	1030	568	931	1670	1640	224	1110	967	1130	884	206	762	1100
Pigeon pea	1040	1350	2140	234	3760	766	685	780	1520	1360	253	1740	890	921	759	173	668	950
Pinto bean	911	1200	2360	98	3180	844	554	714	1390	1220	173	944	865	1140	827	220	599	903
Wheat flour (control)	543	696	802	309	4839	579	379	556	1112	416	251	772	1594	759	442	130	352	687

(Food And Agriculture Organization of the United Nations, 2016) FAO/INFOODS Global Database for Pulses on Dry Matter Basis – version 1.0 (PulsesDM1.0) – 2017

Nutrient Data Laboratory, ARS, USDA National Food and Nutrient Analysis Program, Wave 9o, 2005 Beltsville MD

Table 6: The main antinutrients in pulses.

Categories	Anti-nutritional effect	Nutritional effect
Thermolabile		
Trypsin inhibitors	• reduce protein bioavailability (Sarwar Gilani, Wu Xiao, & Cockell, 2012). • inactivate the digestive enzyme (Adeyemo & Onilude, 2013; Oomah, Caspar, Malcolmson, & Bellido, 2011).	• cancer risk reducing factors. • regulate the activity of trypsin (Lajolo & Genovese, 2002).
Protease inhibitors	• inhibit the activity of trypsin, chymotrypsin and other intestinal proteases (Clemente & Arques, 2014; Župunski et al., 2018). • cause intestinal cell damaging and digestion disturbance (Erdaw, Bhuiyan, & Iji, 2016; Jiang, Jeschke, Hartung, & Cameron, 2008).	• anti-inflammatory activity (Duranti, 2006). • can regulate proteases activity (Muricken & Gowda, 2010).
Lectins	• reduce nutrients bioavailability and solubility (Estrada-Martínez et al., 2017; Gupta et al., 2015)	• can contribute to satiety (McCrory et al., 2010).
Thermostable		
Phytic acid	• lowers the availability of minerals (e.g. calcium, zinc, iron, and magnesium), proteins, and starch (Nilgün Ertaş & Bilgiçli, 2014). • Reduce nutrients solubility, functionality, digestion, and absorption (Gupta et al., 2015; Martín-Cabrejas et al., 2009).	• reduces cholesterol level • protects against intestinal cancer of iron origin. • natural antioxidants • protects from oxidative damage by reducing lipid peroxidation (Shi et al., 2004).
Tannins	• reduce protein digestibility by interaction of protein substrate with ionizable iron (Prasad & Singh, 2015; Sotelo et al., 2010). • cause damage to intestinal cells (Smith & Mackie, 2004). • cause inactivation of digestive enzymes (Adeyemo & Onilude, 2013).	• antioxidant activity (Amarowicz, Pegg, Rahimi-Moghaddam, Barl, & Weil, 2004).
Raffinose	• limits digestion and absorption of nutrients (Wang, Hatcher, Tyler, Toews, & Gawalko, 2010). • produce digestive gases (Kumar et al., 2015; Wang et al., 2010). •	• reduce the risk of intestinal cancer, fortifies the immune system, increases excretion frequency and weight as well as HDL cholesterol level. • promote the growth of the colon microflora and act as prebiotics (Gupta et al., 2015; Gupta & Abu-Ghannam, 2011).
Saponine	• bitter taste (Nilgün Ertaş & Bilgiçli, 2014). • ability to alternate intestinal cells wall (Mamilla & Mishra, 2017; Prasad & Singh, 2015).	• can bond with cholesterol resulting in lower intestinal absorption of cholesterol (Shi et al., 2004). • can bond with heavy toxic metals, which reduces their availability (Kumar et al., 2015; Singh, Singh, Singh, & Kaur, 2017).

Figure 1: Classification and botanical description of pulses.

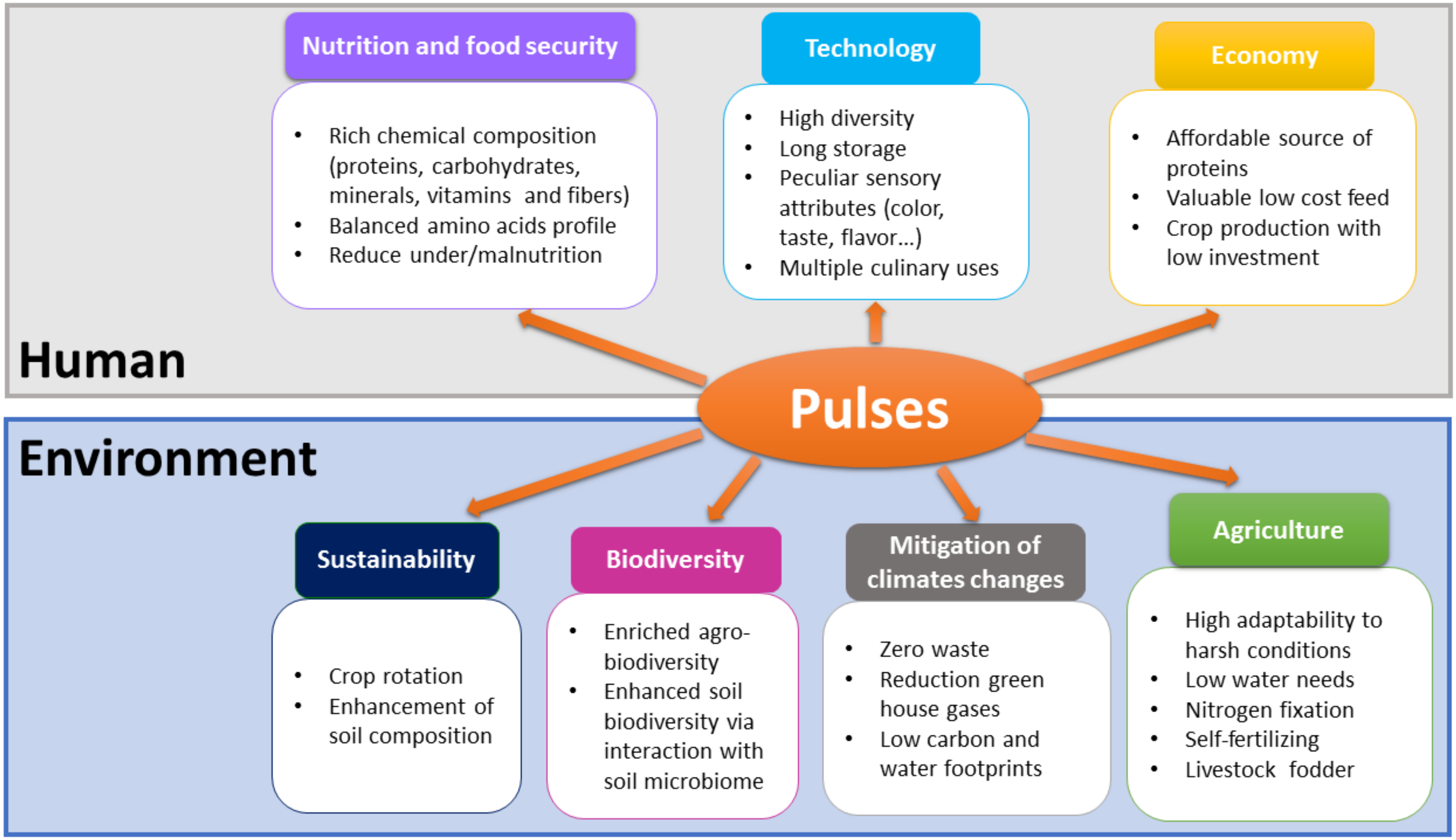

Figure 2: Importance of pulses.