# 14 Crops – Legumes

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## 14.1 Introduction

Legumes belong to the family Leguminosae and consist of oilseeds such as soybeans, peanuts, alfafa, clover, mesquite, and pulses, including the dry grains of peas, chickpeas, lentils, peas, beans, and lupins. Production and use of legumes date back to ancient cultures in Asia, the Middle East, South America, and North Africa. They are cultivated throughout the world for their seeds, harvested and marketed as primary products. Grain legumes are grouped into pulses and oilseeds. The pulses are different from the leguminous oilseeds, which are primarily utilized for oil (Schneider, 2002). There are about 1300 species of legumes, with only about 20 commonly consumed by humans (Reyes-Moreno & Paredes-Lopez, 1993). Notable amongst legume species are chickpeas (*Cicer arietinum*), pigeon pea (*Cajanus cajan*), lentil (*Lens culinaris*), mung bean (*Vigna radiata*), soybean (*Glycine max*), winged bean (*Psophocarpus tetragonoloba*), cowpea (*Vigna unguiculata*), pea (*Pisum sativum*), groundnut (*Arachis hypogaea*), and black gram (*Vigna mungo*), to mention but a few. Some of the most important legumes in the world are peas, beans, peanuts, soybeans, and chickpeas (Reyes-Moreno et al., 2000).

Canada is the leading producer of peas in the world, with about 3,379,400 metric tonnes (MT) produced in 2009 (FAO, 2009). In 2010, the US was the leading global producer of soybeans and the second and third top producer of peas and lentils, respectively (Table 14.1). In the same year, the US was also the fourth leading producer of dry beans and peanuts. Canada again tops the production of lentils and is the seventh and ninth leading producer of soybeans and chickpeas. Similarly, production of dry beans and chickpeas in Mexico is high and the country ranks fifth and eighth in global production, respectively. Brazil was the leading producer of dry beans in 2009. The leading producer of chickpeas in 2009 was India with 7,060,000 MT. Cutting-edge research in plant breeding and agronomic practices in the last several decades has allowed suitable varieties and cultivars for the North American climate to be identified, which has resulted in marked increases in legume production in the region. Although a large percentage of the legumes produced in North America are exported, there is growing interest in expanding domestic consumption, due to increased awareness of their health benefits.

Legumes have a special place in the diet of humans, because they contain nearly 2–3 times more protein than cereals (Reyes-Moreno & Paredes-Lopez, 1993). Cowpeas, for example, contain about 25% protein (Annor et al., 2010). Legumes are also excellent sources of complex carbohydrates and have been reported as beneficial for cardiovascular diseases and diabetes by some researchers (Hu, 2003; Jacobs & Gallaher, 2004), probably due to the large amounts of water-soluble fiber and a large content of phenolics (Enujiugha, 2010). Legumes are also a good source of vitamins (thiamine, riboflavin, niacin, vitamin $B_6$, and folic acid) and certain minerals (Ca, Fe, Cu, Zn, P, K, and Mg), and are an excellent source of polyunsaturated fatty acids (linoleic and linolenic acids) (Augustin et al., 1989). Indeed, several studies suggest that increased consumption of legumes may provide protection against diseases such as cancer, diabetes, osteoporosis, and cardiovascular diseases, among others (Hu, 2003; Pihlanto & Korhonen, 2003; Tharanathan & Mahadevamma, 2003). Legumes further offer a practical avenue for diet diversification as consumers look for greater balance between plant and animal food sources. With growing concerns about the impact of agricultural practices on the environment,

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**Table 14.1** Production of legumes in North America and top 20 global production ranking

| | USA | | Canada | | Mexico | |
|---|---|---|---|---|---|---|
| Legume | Rank | Production (MT) | Rank | Production (MT) | Rank | Production (MT) |
| Beans, dry | 4 | 1442470 | 15 | 253700 | 5 | 1156250 |
| Chickpea | 15 | 87952 | 9 | 128300 | 8 | 131895 |
| Groundnut, with shell | 4 | 1885510 | | | | |
| Lentil | 3 | 392675 | 1 | 1947100 | | |
| Pea, dry | 2 | 645050 | 1 | 2862400 | | |
| Soybean | 1 | 90605500 | 7 | 4345300 | | |

MT, metric tonnes.
Source: http://faostat.fao.org/site/339/default.aspx.

addition of legumes in crop rotation cycles can have beneficial impacts as they have the capacity to fix nitrogen in soils, thereby reducing the need for chemical fertilizers.

Peanuts are the most commonly consumed (by humans) and convenient of the legumes as they form part of the mainstream diet and can be easily obtained and consumed as roasted seeds or in the form of peanut butter. In the US, for example, peanuts and peanut butter comprise over two-thirds of all nut consumption (www.peanut-institute.org/peanut-facts/history-of-peanuts.asp, accessed 18 November 2013). Soybeans and pulse legumes, on the other hand, are more alien to the North American diets. Factors that have limited their consumption in North America include the longer time required for their preparation, the possible gastrointestinal (GI) discomfort due to the presence of indigestible carbohydrates which ferment in the GI tract causing gas and bloating, and their typical beany flavor. Extensive research in breeding, food quality, and processing has helped to overcome some of these limitations, increasing the acceptability of legumes in the North American diet and facilitating their use in food formulation.

Although legumes are rich in proteins, the quality of their protein is not nutritionally adequate. This is because they lack sulfur-containing amino acids such as methionine and cysteine. These limiting amino acids are, however, complemented by the use of legume cereal blends in diets. Cereals, being rich in sulfur-containing amino acids, complement the legume proteins, hence improving the quality of the protein. Other factors such as low protein digestibility, presence of antinutritional factors such as trypsin inhibitors, lectins, phytates, polyphenols, and flatulence factors make some legume seeds underutilized (Enujiugha, 2005; Mubarak, 2005; Ragab et al., 2010). Most of these antinutritional factors can, however, be reduced or eliminated by various processing techniques. In this chapter, we discuss different processing technologies applied to legumes, which are grouped as traditional and modern processing technologies.

## 14.2 Technologies involved in legume processing

The processing of legumes can be conveniently grouped into traditional and modern, depending on the complexity of the processing steps involved and the types of equipment used. Traditional methods include simple technologies and simple equipment that can be used at household level, whereas modern processing includes much more sophisticated processes and equipment at industrial level.

Legumes can be cooked and consumed as fresh beans or after drying, which is done to extend their shelf life. The term "pulse," for example, specifically refers to the dried grains of pea, chickpea, bean, lentil, and lupin, which distinguishes them from the fresh beans. Cooking of legumes inactivates antinutritional factors such as trypsin and amylase inhibitors, thus improving their nutritional quality. As is done in Asia and other parts of the world, in North America, fresh soybeans in the pod, peas, green beans, sugar snap beans, and string beans can be cooked and eaten as a side dish or with salads. Peanuts and soybeans are also roasted whole and consumed as is or used to prepare peanut butter and soybean butter. Increasingly, peas have been subjected to similar processing and are roasted for consumption as a snack or further processed to obtain pea butter.

The majority of soybean and pulses produced in North America are dried post harvest. For pulses, the seeds can be subsequently dehulled and split, which reduces cooking time. Details on the techniques used for primary processing of legumes (e.g. harvesting, cleaning, sorting, dehulling, splitting) are described elsewhere (Erskine et al., 2009; Snyder & Kwon, 1987; Subuola et al., 2012; Tiwari et al., 2011).

Dry legume seeds (e.g. soybeans, alfalfa, clover, pea, beans, chickpeas, lentils) are sometimes allowed to germinate after soaking and sold in the sprouted form. Sprouted legumes are of interest nutritionally, as the germination process helps to increase protein digestibility and mineral bioavailability, and in some instances can reduce the concentration of tannins, phytic acid, and indigestible carbohydrates (Boye et al., 2012). Sprouting will be discussed later in this chapter.

Another technique used to preserve and extend the shelf life of legumes, particularly pulses, is canning, which will be discussed later in this chapter. Whole seeds are first soaked, blanched, and cooked and then packaged in cans with a variety of sauces, which eases their use in food preparation. A wide variety of canned legumes can be found in North American supermarkets, with the most popular perhaps being canned baked beans.

Another growing market for both household use and in the food service sector is the frozen precooked legumes category. Frozen vegetables are perceived by some consumers to have higher nutritional value than canned foods. Rickman et al. (2007) point out that this perception may not always be true, as the effects of processing, storage and cooking are highly variable by commodity. Nevertheless, there is a growing market for precooked frozen legumes, which offer convenience when they can be quickly warmed on stove-top or in the microwave prior to consumption. The export market for frozen vegetables in North America was valued at US$292 M in 2011 (www.icongrouponline.com, accessed 18 November 2013). Individually quick-frozen (IQF) vegetables may be classified as ready-to-use, reheat-and-serve foods. They are first blanched/cooked prior to quick-freezing, which helps to preserve physical and nutritional quality.

Infrared heating is another technique applied to whole pulse seeds to decrease the time required for cooking. The process is sometimes called micronization. A company located in Canada, Infraready Products Ltd. (www.infrareadyproducts.com, accessed 18 November 2013), uses this technique to precook pulses (i.e., peas, beans, chickpeas and lentils). Described benefits of micronization include shorter cooking times, increased water and moisture absorption and retention, decreased microbial and enzymatic activity, increased shelf life, softer texture and flavor enhancement due to the addition of toasted notes to finished food products. Pulses can also be fully precooked in water and then dehydrated and sold as is or ground into flour, which will be discussed later in this chapter.

A variety of food products can be processed directly from dried legume seeds. In traditional markets, soybeans are processed into soymilk, tofu, yuba, miso, natto, sufu, and tempeh (Keshun, 1997). With the growing migrant population and the increasing trend towards exotic foods, these traditional products are now available in North America. Similarly, whole pulses are typically used to prepare soups, sauces, fried and baked products in places like India, Africa, and South America; these food products are now being made from pulses in North America. Research is further exploring novel uses and promising application areas of legumes for the North American market (Figure 14.1).

## 14.3 Traditional processing technologies

The traditional processing of legumes is labor intensive and is mostly done by women, especially in developing countries in Asia and Africa. The major traditional techniques used in the processing of legumes are soaking, dehulling, milling, boiling/cooking, roasting, pounding and grinding, frying, steaming, germination, fermentation, and popping, among others. Irrespective of the type of food that is prepared from legumes, they are taken through at least one of these processes. In this section, we discuss what some of these technologies are and the principles behind them.

### 14.3.1 Soaking

Legumes are primarily soaked in water and/or salt solutions (0.25–1%) to soften the cotyledon, which then hastens cooking (Silva et al., 1981). Soakaing involves adding water and/or salt solution to the legumes and discarding the water after a period of time or cooking with the soak water. Sodium chloride, acetic acid, and sodium bicarbonate solutions have been used in the soaking of legumes (Huma et al., 2008). Different soaking times have also been reported (Huma et al., 2008; Xu & Chang, 2008), but in most cases, the soaking is done overnight. Soaking

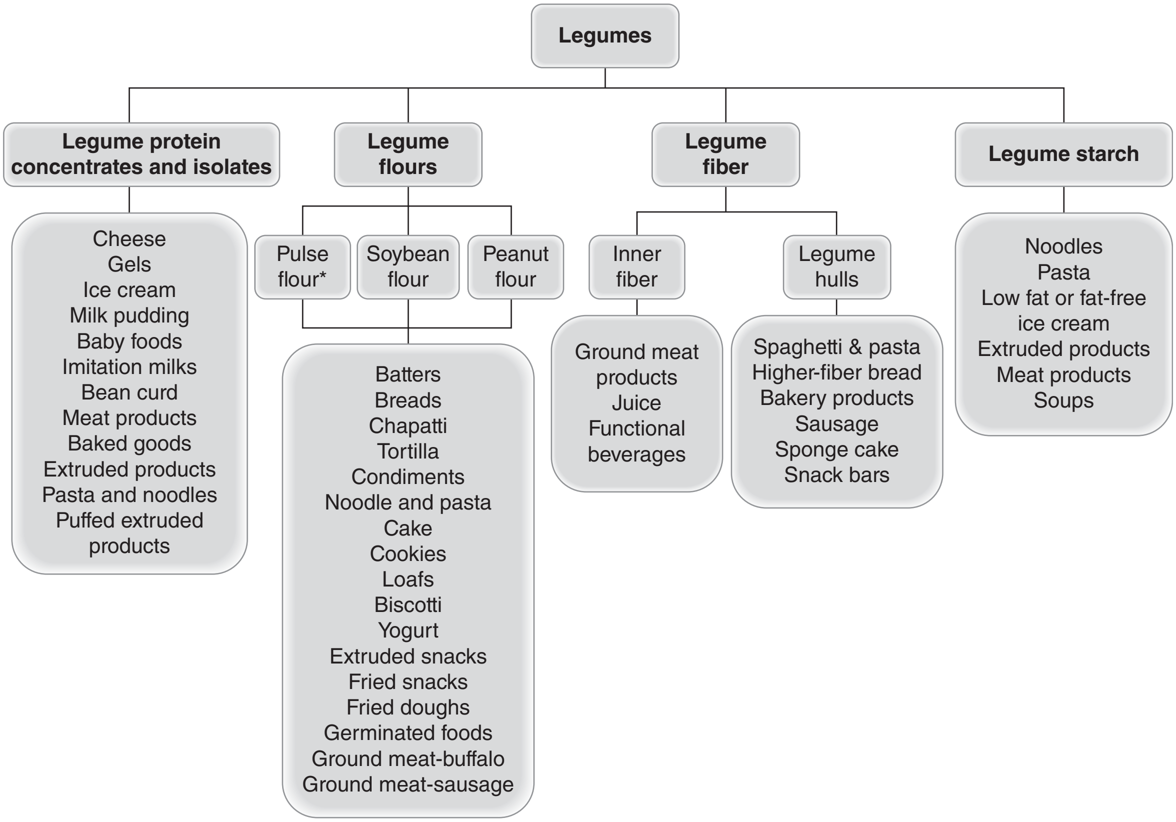


**Figure 14.1** Potential and current food applications of legume flours and fractions. ∗Pulse flours include flours prepared from yellow pea, green gram, cowpea, navy bean, faba bean, field pea, lupin, lentils, great northern bean, pinto bean, red bean, white bean, black bean, winged bean, and pigeon pea.

of legumes can be done in either warm water or water at ambient temperature. Beside its primary role of shortening the cooking times of legumes, soaking has been reported to significantly reduce the phytate and phytic acid contents of legumes (Toledo & Canniatti-Brazaca, 2008). This was observed when legumes were not cooked with the soaking water. The flatulence factors in legumes are also reduced by soaking, as a result of the leaching out of stachyose and raffinose (Shimelis & Rakshit, 2005). These oligosaccharides are used as substrates by microorganisms in the large intestines, resulting in the production of carbon dioxide, leading to flatulence and intestinal discomfort. The addition of sodium bicarbonate to the soak water results in significant reduction in stachyose and raffinose. Soaking also increases the protein digestibility of legumes (Toledo & Canniatti-Brazaca, 2008), as confirmed in chickpeas, lentils, and different types of legumes (Martín-Cabrejas et al., 2009).

Soaking further results in the reduction of the mineral contents of legumes, due to the loss in the soaking water, especially when the water is discarded; however, their bioavailability is increased after soaking (Martín-Cabrejas et al., 2009). The increase in the bioavailability of minerals may be attributed to the reduction in antinutritional factors during soaking. These antinutritional factors are known to bind to the minerals in legumes, making them unavailable to the human body. Generally, soaking and cooking legumes without the soaking water reduces their carbohydrate contents (Martín-Cabrejas et al., 2009).

### 14.3.2 Cooking

The cooking of legumes has been practiced for years. It is one of the most common processing techniques applied to legumes, and involves boiling the legume seeds in water till they are soft. Traditionally, determination of the required softness of cooked legumes is done by pressing the legumes with the thumb. Several changes occur during the cooking of legumes apart from softening: gelatinization of starch, denaturation of proteins, and browning of the seeds (Enujiugha, 2005: Onigbinde & Onobun, 1993). Besides reducing the antinutritive factors in legumes, cooking reduces the amounts of stachyose and raffinose. The longer cooking times required have, however, been an obstacle to legumesuse. To reduce the legume cooking times, potash has been used traditionally to help soften the legume cotyledons. Sodium bicarbonate, trisodium phosphate, and ammonium carbonates have also been exploited to reduce the cooking times of legumes (Bueno et al., 1980).

### 14.3.3 Fermentation

Solid-state fermentation (SSF) is one of the alternative technologies for processing a great variety of legumes and/or cereals with the aim of improving their nutritional quality and obtaining edible products with palatable sensory characteristics (Reyes-Moreno et al., 2004). The advantages of fermentation include the development of flavor, texture, taste, reduction in product volume and the increase in product stability and shelf life through the preservation of the foods (Steinkraus, 2002). Legumes have been fermented into a variety of products. Notable among these products are tempeh and soy sauce, which are particularly popular in Asian countries.

Tempeh is a traditional fermented food produced with different strains of *Rhizopus* species (*R. oligosporus, R. stolonifer, R. oryzae, R. arrhizus*) fermenting boiled and dehulled soybeans (Annor et al., 2010: Keuth et al., 1993). It has a pleasant mushroom-like aroma and a nutty flavor, making it an excellent option for meat, fish and poultry products (Pride, 1984). During the fermentation process, stachyose and raffinose are broken down to digestible sugars. The fermentation process also improves the flavor, nutritional and functional properties of the product (Bavia et al., 2012). Even though soybeans are the main legumes used for the preparation of tempeh, other substrates have been used, e.g. cowpeas (Annor et al., 2010) and chickpeas (Reyes-Moreno et al., 1993). The process variables for the production of tempeh from chickpeas were optimized by Reyes-Moreno and colleagues (1993). According to their study, the optimum combination of process variables for production of optimized chickpea tempeh flour through the SSF process was incubating at 34.9 °C for 51.3 h. The chickpea tempeh was prepared by soaking the chickpeas at 25 °C for 16 h in four volumes of acetic acid solution (pH 3.1). The seeds were then drained and their seed coats removed. The cotyledons were then cooked for 30 min and then cooled to 25 °C, packed in polyethylene bags and fermented with a suspension of *R. oligosporus* spores.

Soy sauce is a traditional Asian fermented soybean product that has gained international acceptance as a condiment or seasoning sauce due to its distinctive flavor. A combination of soybeans and wheat is normally used as the raw material. The soybeans and wheat are first fermented with *Aspergillus oryza* and then yeast and lactic acid bacteria are added later, after the addition of brine solution (8%) (Zhao et al., 2013). Two types of fermentation for soy sauce can be used: low-salt solid state and high-salt liquid state. The fermentation times for these two different types of fermentations differ significantly; while the former takes about 1 month, the latter takes as long as 6 months. Different concentrations of brine are also used for the different fermentation types. For the low-salt solid state fermentation, about 8% is used, while about 17% is used for the high-salt liquid state fermentation. The different fermentation types result in different tastes and flavors, with the high-salt liquid state fermented soy sauces having an edge over the taste and flavor of the low-salt solid state fermented product. Soy sauce has been reported to have antihypertensive properties, due to the presence of angiotensin I-converting enzyme, which was found to decrease blood pressure in hypertensive rats (Kinoshita et al., 1993).

The list of fermented legume foods is endless, with soybean arguably being the most fermented legume. Some of the products are *dawadawa*, from the African locust bean (*Parkia tilicoidea*), natto from soybeans, tempe *kedelee* from soybeans, *oncomhitam* from peanuts, *ketjap* (soy sauce) from black soybeans and *channakiwaries* prepared from bengal gram (*Cicerarietinum L.*) and black gram (*Vignamungo*) flour.

### 14.3.4 Dehulling

Dehulling involves the removal of the hulls of grain seeds, in this case legume seeds. It is one of the basic processing steps in legume processing. Dehulling can be done traditionally with mortar and pestle, which makes the process laborious and time consuming (Ehiwe & Reichert, 1987). The dehulling of legumes results in reduction of fiber and tannin content, and, most importantly, affects the appearance, texture, cooking quality, digestibility, and palatability of the grains (Deshpande et al., 1982). It has been demonstrated that there are marked differences in the dehulling efficiency of legumes (Reichert, 1984). Soybeans (*Glycine max*), faba beans (*Vicia faba equine* L.) and field peas (*Pisum sativum* L.) have better dehulling efficiencies (about 70%) compared to the others. These dehulling efficiencies were attributed to the resistance of seed splitting during dehulling and also to fact that the seed coat of these legumes is loosely bound to their cotyledons (Ehiwe & Reichert, 1987).

### 14.3.5 Germination/sprouting

Germination is one of the most common and effective legume processing methods, with the aim of improving nutritional quality. It can be defined as the transformation of seeds (herein referred to as legumes) from their dormant state to a metabolically active state, involving the mobilization of stored reserves of these seeds. As a result, there is a rapid increase in respiration, synthesis of proteins and nucleic acids, and the elongation and division of cells (Kadlec et al., 2008). Germination is normally preceded by soaking. During germination, the degradation of stored carbohydrates in the seeds by enzymes takes place. This results in significant changes in the physicochemical characteristics of the legumes, including the modification of antioxidant activities (López-Amorós et al., 2006). The process of germinating legumes, as is traditionally practiced, involves soaking seeds in water for 24 h at room temperature, draining and then spreading them on a damp cloth for about 48 h. In some cases where traditional germination is done on a large scale, large wet baskets are used.

### 14.3.6 Puffing

Puffing is one of the traditional technologies used to process legumes. It is commonly applied to chickpeas and peas, resulting in a light and crispy product. Puffed legumes are commonly eaten as snack foods, though they can also be milled into flour and used for other purposes. Traditionally, puffed legumes are prepared by soaking the legumes in water for about 15–20 min, followed by draining the water. The wet grains are then tempered in a closed vessel for about 4 h, after which they are cooked in sand, heated to about 200 °C for about a minute. This normally results in the expansion of the grains, leading to the splitting of the husk of the legumes. Puffed legumes are known to retain all the nutrients and also result in improved protein and carbohydrate digestibility (Baskaran et al., 1999).

## 14.4 Modern processing technologies

Modern processing technologies for legumes involve the use of sophisticated equipment and result in the mass production of products. Some of these technologies include extrusion cooking, high-pressure cooking, air classification, agglomeration, and canning. In this section, some of these technologies as applied to the processing of legumes and their effects on the nutritional and physical characteristics of legumes are discussed.

### 14.4.1 Extrusion cooking

Extrusion cooking is a high-temperature, short-time process that can be applied to foods to modify and/or improve their quality attributes. It consists of the thermomechanical cooking of foods at high temperatures, pressure and shear, generated inside a screw-barrel assembly (Battacharya & Prakash, 1994). Extrusion has been applied to legumes for the production of ready-to-eat products. Attempts to use extrusion cooking as a means to decontaminate aflatoxin in peanuts (Grehaigne et al., 1983; Saalia & Phillips, 2011) and canavanine in jack beans (Tepal et al., 1994) have been mentioned.

Extrusion has several effects on the nutritional properties of the resulting extruded products. Improvements in the protein and starch digestibility of extruded faba and kidney beans were reported by Alonso et al. (2000). According to Phillips (1989), the conditions used in extrusion cooking result in physical and chemical transformations such as protein cross-linking (Stanley, 1989), isopeptide bonding (Burges & Stanley 1976), or amino acid racemization, that directly influence the nutritional composition of extruded products. Extrusion cooking has also been effectively used in the production of textured vegetable protein (TVP) and textured soy protein (TSP), used extensively as food ingredients.

The extruder consists of a sturdy screw or screws rotating inside a smooth or grooved cylindrical barrel. The barrel can be heated externally for certain applications. For the production of extruded legume products, legume flour, which is conditioned to a moisture content of about 20–25% with live steam, is fed into the extruder. As the flour-water mixture goes through the barrel, it is heated rapidly by friction and external heat; coupled with high pressures, temperatures as high as 150–180 °C are attained. The legume flour-water mixture then goes through a process called thermoplastic "melting," also known as thermoplastic extrusion. The intense heat and pressure conditions applied to the product result in the denaturation of the soy proteins and puffing of the mixture. The extrudate is then cut and dried.

### 14.4.2 High-pressure cooking

High-pressure cooking involves the application of hydrostatic pressure of several hundred MPa to foods for the purpose of sterilization, protein denaturation, and control of enzyme and chemical reactions, amongst others (Estrada-Giron et al., 2005). It basically involves the cooking of food in a high-pressure cooker. High-pressure cooking, also commonly referred to as high hydrostatic pressure (HHP) cooking, is gaining worldwide interest, especially in Japan, the US and Europe, because of its advantages over most processing methods. In the US, consumers can purchase HHP-processed sauces, oysters, and guacamole (Estrada-Giron et al., 2005). HHP results in significant inactivation of microorganisms (Knorr 1993), improved food quality and retention of ingredients in the products (Cheftel, 1991). HHP can also be used in the modification of texture, whipping, emulsification and dough-forming properties of foods (Hoover, 1989). HHP has been applied to the processing of legumes, especially soybeans. HHP-produced tofu was found to have a much longer shelf life due to the significant reduction in its microbial population (Prestamo et al., 2000). The solubilization of protein from whole soybean grains, subjected to pressure of up to 700 MPa, has also been reported (Omi et al., 1996). The activity of lipoxygenase, an enzyme which is responsible for the off-flavors produced in soybeans, has been found to be sensitive to high pressures (Ludikhuyze et al., 1998).

### 14.4.3 Canning

Canning is a heat sterilization process applied to foods to ensure they are commercially sterile (i.e. the products are free from microorganisms capable of growing in the food at normal non-refrigerated temperatures). Properly sealed and heated canned foods should remain stable and indefinitely unspoiled in the absence of refrigeration. The effectiveness of the canning process is determined by the type of food, pH, container size and consistency or bulkiness of the food, but heating of food for longer than necessary is undesirable, as the nutritional and eating quality of foods are affected negatively by prolonged heating (Brock et al., 1994). Canning, like many other food processes, is applied to legumes to improve their shelf life. Canning of legumes is mainly composed of two processes: soaking/blanching and thermal processing/heat sterilization. Soaking is done before canning to remove foreign material, facilitate cleaning, aid in can filling through uniform expansion, ensure product tenderness, and improve color. Soaking also results in the reduction of antinutritive factors in the legumes, due to their leaching out (Uebersax et al., 1987). Blanching inactivates enzymes, which might produce off-flavors, but also softens the product and removes gases to reduce strain on can seams during retorting (Beckett, 1996). Afoakwa et al. (2006) optimized the preprocessing conditions for the canning of Bambara groundnuts. They concluded that soaking time of 12 h, blanching time of 5 min and sodium hexametaphosphate salt concentration of 0.5% gave the best quality canned product from Bambara groundnut with acceptable quality characteristics.

Conditions for heat sterilization of low-acid foods are defined to ensure that all spores of *Clostridium botulinum* are destroyed and to prevent the spoilage of the product by heat-resistant, non-pathogenic organisms. Sterilization should normally be performed at 121 °C for at least 3 min (Beckett, 1996). In the case of legumes, additional sterilization would also provide adequate softening of the seeds (van Loggerenberg, 2004). Canning has significant effects on the nutritional properties of legumes. Wang et al. (1988) found that canning decreased the protein content of drained beans, with the exception of one cultivar. Canning results in nitrogenous components, such as amino acids and small chain polypeptides, leaching from bean tissue into brine (Drumm et al., 1990); crude protein also leaches into the canning medium (Lu & Chang, 1996). Canning of legumes also causes mineral losses. Iron, magnesium, manganese, potassium, and zinc losses occur during soaking, blanching and/or thermal processing, but phosphorus and copper levels remain the same in canned beans. The sodium and chloride levels increase in canned beans, due to the sodium chloride (NaCl) added to the filling medium of cans (Lopez & Williams, 1988).

### 14.4.4 Air classification

Air classification is a technique for the dry separation of particles from finely ground powders and flours, according to their size, shape, and density. Air classification is typically applied to pulse products and is a relatively simple technique that allows expansion of product offerings. It has been proven as an effective method for the production of starch-rich and protein-rich fractions of meals (King & Dietz, 1987). Air classification has been carried out on pea (*P. sativum*), faba bean (*V. faba*), mung bean (*Vigna radiata*), green lentil (*Lens culinaris*), navy bean (*Phaseolus vulgaris*), baby lima bean (*Phaseolus lunatus*), and cowpea (*Vigna unguiculata*) (Tyler et al., 1981). The first process of air classification involves milling. Tyler et al. (1981) used a pin mill when they studied the air classification of legumes. In their study, dehulled legume seeds were milled with a pin mill and then fractioned into starch fraction and protein concentrate using an air classifier. These fractions were remilled several times and air classified again to increase the quality and also the yield of the protein concentrates. Air classification, aside from separating the starch and protein fractions, results in enrichment of the fractions.

### 14.4.5 Agglomeration

Agglomeration, in general, can be defined as a process during which primary particles are joined together so that bigger porous secondary particles (conglomerates) are formed (Palzer, 2005). According to this definition, even caking of hygroscopic raw materials during storage can be regarded as a kind of undesired agglomeration. Agglomeration is a physical phenomenon and can be described as the sticking of particulate solids, which is caused by short-range physical or chemical forces among the particles themselves due to physical or chemical modifications of the surface of the solid. This phenomenon is triggered by specific processing conditions, or binders and substances, which adhere chemically or physically on the solid surfaces to form a bridge between particles (Pietsch, 2003). The basic principle of the process of agglomeration is that powdery flour is dispersed in a humid atmosphere to wet the surface of the flour particles, resulting in the particles adhering to each other. This process has been used in the preparation of cous-cous in North Africa. Agglomeration enhances the swelling and dispersion properties of legume flours.

## 14.5 Ingredients from legumes

### 14.5.1 Oil

Due to their high oil content, soybeans and peanuts have served as important raw materials for oil production. Soybean oil production in the US in 2011 was 8.4 million MT (www.soystats.com, accessed 18 November 2013), whereas peanut oil production is more limited and was 89 thousand MT in 2012 (www.indexmundi.com, accessed 18 November 2013). Even though Mexico and Canada rank seventh and 15th in global production of soybean oil, respectively, there is hardly any peanut oil production in Canada.

Hydraulic pressing, expeller, solvent extraction and combinations of these techniques are the main processes used for vegetable oil extraction. With a few exceptions, the process for extracting oil from soybeans and peanuts is very similar (Figure 14.2). Typically, the oilseed is first cleaned to remove foreign materials, dried if needed to facilitate dehulling and cracking, which allows the seeds to be broken into smaller pieces, followed by conditioning and flaking. The flaking process involves passage of the broken pieces between rolls, which ruptures the oil cells and expands the surface area for solvent penetration and subsequent oil extraction.

Hexane is the most common solvent used for oil extraction. The miscella obtained after solvent extraction contains a mixture of oil and solvent, which is passed through a solvent recovery system to remove solvent. The crude oil remaining is subjected to further refining to obtain edible oil and other derived products. The defatted flakes are passed through a desolventizer/toaster to remove residual solvent. The meal obtained is rich in protein, and can be used as is or further processed downstream to extract protein. Lui (1997) provides further detail on soybean oil extraction processes. Concerns about trace remnants of hexane in solvent-extracted defatted oilseed meals have spurred research on alternative defatting techniques such as the use of other solvents, mechanical extraction, enzyme-assisted aqueous extraction, and supercritical extraction (Russin et al., 2011).

### 14.5.2 Flours

Whole, dehulled and defatted legume seeds, flours, and flakes can be milled to obtain a variety of flour products. Subuola et al. (2012) and Tiwari et al. (2011) provide an overview of the methods used to obtain flours from soybean, pulses, and peanuts. The major component found in legume flours is carbohydrate, which can range from 25% to 68%. Depending on whether flours are defatted or not, protein content can range from 17% to 56%. Table 14.2 presents the composition of legume flours prepared using a variety of processing techniques.

Legume flours are of interest in food processing due to both their nutritional and functional properties. Functional properties that aid in food formulation and processing include protein solubility, water holding

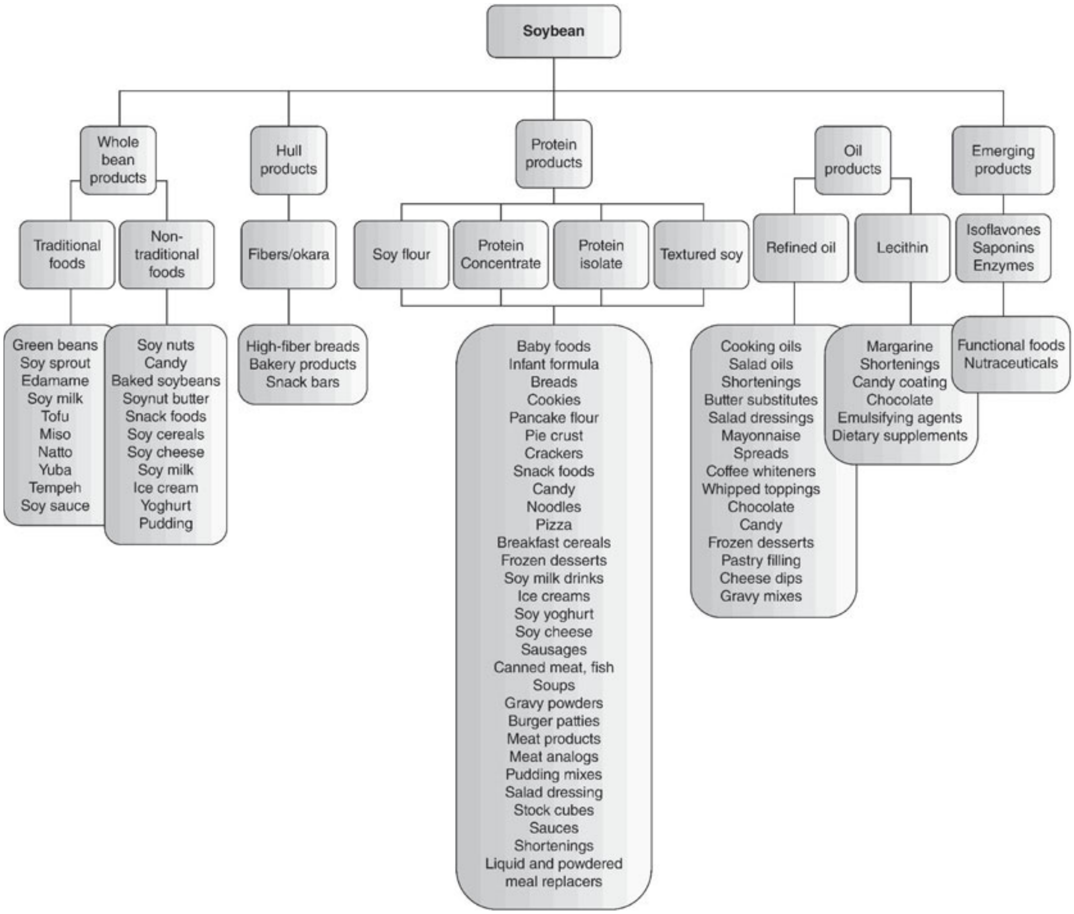


**Figure 14.2** Soybean foods and ingredients. Reprinted from L'Hocine & Boye (2007), with permission from Taylor & Francis.

**Table 14.2** Chemical composition of legume flours and legume protein concentrates/isolates

| | Processing techniques | Protein (%) | Fat (%) | Carbohydrates (%) | Moisture (%) | Ash (%) | Starch (%) | Crude fiber (%) | References |
|---|---|---|---|---|---|---|---|---|---|
| **Legume flours** | | | | | | | | | |
| Full-fat Desi chickpea flour | Centrifugal mill (5-mesh sieve with 1.5 mm pore size) | 22.3 | 5.16 | 39.19 | db | 3.37 | | | (Mondor et al., 2010) |
| Full-fat Kabuli chickpea flour | Centrifugal mill (5-mesh sieve with 1.5 mm pore size) | 18.9 | 6.70 | 71.24 | db | 3.16 | | | (Mondor et al., 2010) |
| Kabuli chickpea flour | Centrifugal grinding mill and dehulling | 16.71 | 7.34 | 61.14 | 12.06 | 2.76 | | | (Boye et al., 2010a) |
| Desi chickpea flour | Centrifugal grinding mill and dehulling | 20.52 | 5.23 | 61.94 | 9.26 | 3.04 | | | (Boye et al., 2010a) |
| Defatted chickpea flour | Grinding and sieving (80-mesh sieve), defatted (10% w/v hexane) and air dried | 17.2 | 0.3 | | | 2.8 | | 1.1 | (Paredes-López et al., 2006) |
| Chickpea flour | Grinding with a coffee mil, sieving through a 60- mesh sieve | 21.37 | 7.17 | 58.92 | 7.40 | 2.98 | | 2.16 | (Bencini, 2006) |
| Chickpea flour | NR | 22.9 | 6.4 | | 10.4 | 2.83 | 40.4 | | (Marconi et al., 2000) |
| Bengal gram flour (*Cicer arietinum*) | Dehulling, grinding and sieving (40- or 60-mesh) | 21.2 | 5.6 | 66.1 | 3.2 | 2.6 | | 1.8 | (Nagmani & Prakash, 1997) |
| Whole pea flour | Grinding and passing through a 4 mm screen | 23.7 | | | 13.9 | 3.28 | 52.7 | 5.5 | (Maaroufi et al., 2000) |
| Pigeon pea flour | Boiling, dehulling and dry milling | 22.4 | 2.63 | 59.4 | 5.24 | 5.76 | | 3.82 | (Oshodi & Ekperigin, 1989) |
| Pea flour | NR (Fernández-Quintela et al., 1997) | 23.93 | 3.12 | 59.39 | | 2.58 | | 8.77 | |
| Yellow pea flour | Centrifugal grinding mill and dehulling | 21.09 | 2.01 | 60.29 | 14.19 | 2.42 | | | (Boye et al., 2010a) |
| Field pea flour | Commercial | 25.0 | 1.1 | | db | 2.7 | 55.7 | 1.9 | (Sosulski & McCurdy, 1987) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Green lentil flour | Centrifugal grinding mill and dehulling | 23.03 | 0.82 | 63.08 | 10.68 | 2.39 | | | (Boye et al., 2010a) |
| Red lentil flour | Centrifugal grinding mill and dehulling | 25.88 | 0.53 | 63.10 | 9.27 | 2.34 | | | (Boye et al., 2010a) |
| Lentil flour | Grinding of whole flours | 20.6 | 2.15 | 56.1 | 11.2 | 2.80 | | 6.83 | (de Almeida Costa et al., 2006) |
| Lentil flour | Dehulling and grinding into powder by passing through a 0.4 mm screen | 32.38–33.39 | 1.95–2.10 | 47.04–51.49 | 7.98–10.37 | 2.70–3.78 | | 2.43–4.13 | (Suliman et al., 2006) |
| Lentil flour | Dehulling, grinding and sieving (40- or 60-mesh) | 26.0 | 0.8 | 65.2 | 5.0 | 2.3 | | 0.7 | (Nagmani & Prakash, 1997) |
| Common bean flour | Grounding the whole flours | 20.9 | 2.49 | 54.3 | 9.93 | 3.80 | | 8.55 | (de Almeida Costa et al., 2006) |
| Black gram flour (*Phaseolus mungo*) | Dehulling, grinding and sieving (40- or 60-mesh) | 23.2 | 1.4 | 67.9 | 3.3 | 3.3 | | 0.8 | (Nagmani and Prakash, 1997) |
| Green gram flour (*Phaseolus aureus*) | Dehulling, grinding and sieving (40- or 60-mesh) | 25.6 | 1.3 | 67.7 | 1.3 | 3.3 | | 0.8 | (Nagmani & Prakash, 1997) |
| Common bean flour | NR | 20.8 | 2.6 | | 10.4 | 3.68 | 37.9 | | (Marconi et al., 2000) |
| Defatted peanut flour | Dehulling, flaking and defatting (using butane and propane) | 55.88 | 1.50 | 25.14 | 8.12 | 4.85 | | | (Wu et al., 2009) |
| Defatted soybean flour | Grinding flakes to pass through 100-mesh or finer, and defatting | 50.5 | 1.5 | 34.2 | | 5.8 | | 3.2 | (Wolf, 1970) |
| Soybean flour | Commercial | 48.2 | 0.9 | | db | 5.8 | 2.4 | 4.2 | (Sosulski & McCurdy, 1987) |
| **Ranges** | | 16.71–55.88 | 0.3–7.34 | 25.14–67.9 | 1.3–14.19 | 2.34–5.76 | 2.4–55.7 | 0.8–8.77 | |
| **Legume protein concentrates** | | | | | | | | | |
| Soybean protein concentrate | Aqueous alcohol washing, IEP and leaching | 66.2 | 0.3 | | 6.7 | | | | (Wolf, 1970) |

(*Continued*)

**Table 14.2** (*Continued*)

| | Processing techniques | Protein (%) | Fat (%) | Carbohydrates (%) | Moisture (%) | Ash (%) | Starch (%) | Crude fiber (%) | References |
|---|---|---|---|---|---|---|---|---|---|
| Full-fat Desi chickpea protein concentrate (IEP) | Alkaline extraction/IEP | 78.6 | 11.37 | 6.88 | db | 3.18 | | | (Mondor et al., 2010) |
| Full-fat Kabuli chickpea protein concentrate (IEP) | Alkaline extraction/IEP | 69.9 | 21.55 | 5.39 | db | 3.16 | | | (Mondor et al., 2010) |
| Defatted Desi chickpea protein concentrate (IEF) | Alkaline extraction/IEP | 86.9 | 3.71 | 5.92 | db | 3.47 | | | (Mondor et al., 2010) |
| Defatted Kabuli chickpea protein concentrate (IEF) | Alkaline extraction/IEP | 85.6 | 10.44 | 0.59 | db | 3.37 | | | (Mondor et al., 2010) |
| Peanut protein concentrate (IPPPC) | Acid extraction/IEP | 72.35 | 1.13 | 17.97 | 1.48 | 3.05 | | | (Wu et al., 2009) |
| Peanut protein concentrate (AAPPC) | Aqueous alcohol precipitation | 69.54 | 0.70 | 16.06 | 1.51 | 2.06 | | | (Wu et al., 2009) |
| Peanut protein concentrate (IAPPC) | IEP and alcohol precipitation | 71.49 | 0.84 | 16.46 | 1.49 | 2.03 | | | (Wu et al., 2009) |
| **Ranges** | | 66.2–86.9 | 0.3–21.55 | 0.59–17.97 | 1.48–6.7 | 2.03–3.47 | | | |
| **Legume protein isolates** | | | | | | | | | |
| Micelle chickpea protein isolate | Micellization (NaCl extraction and ultrafiltration) from defatted flour | 87.8 | 1.8 | | | 2.3 | | 0.2 | (Paredes-López et al., 2006) |
| Isoelectric chickpea protein isolate | IEP (alkaline extraction) from defatted flour | 84.8 | 1.9 | | | 2.7 | | 0.2 | (Paredes-López et al., 2006) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Peanut protein isolate | IEP (pH 4.5) and alcohol precipitation | 96.65 | 0.20 | 0.36 | 1.61 | 2.22 | | | (Wu et al., 2009) |
| Soybean protein isolate | Alkaline extraction from defatted flour or flask, IEP, centrifugation/ filtration | 92.8 | <0.1 | | 4.7 | | | | (Wolf, 1970) |
| Soybean protein isolate | Commercial | 82.3 | 0.4 | | db | 4.0 | 1.8 | 0.6 | (Sosulski & McCurdy, 1987) |
| Field pea protein isolate | Alkaline extraction and IEP | 80.3 | 1.7 | | db | 4.4 | 2.7 | 1.3 | (Sosulski & McCurdy, 1987) |
| Faba bean protein isolate | Acid extraction and IEP | 86.3 | 2.0 | | db | 3.9 | 1.8 | 0.6 | (Sosulski & McCurdy, 1987) |
| Pea protein isolate | Dehulling, alkaline extraction, centrifugation and lyophylizing | 84.09 | 3.32 | 6.57 | | 7.88 | | 5.01 | (Fernández-Quintela et al., 1997) |
| Faba bean protein isolate | Dehulling, alkaline extraction, centrifugation and lyophylizing | 81.24 | 3.83 | 8.47 | | 7.89 | | 6.90 | (Fernández-Quintela et al., 1997) |
| Soybean protein isolate | Dehulling, defatting, alkaline extraction, centrifugation and lyophylizing | 82.16 | 1.46 | 5.64 | | 7.73 | | 3.17 | (Fernández-Quintela et al., 1997) |
| **Ranges** | | 80.3–96.65 | 0.1–3.83 | 0.36–8.47 | 1.61–4.7 | 2.22–7.89 | 1.8–2.7 | 0.2–6.90 | |

db, dry basis; IEP, isoelectric precipitation; NR, not reported.

**Table 14.3** Functional properties of legume flours, protein concentrates, and isolates

| | Protein content (%) | PS (%) | WHC | FAC | LGC | BD (g/mL) | FE | FC | FS | EC | EA (%) | ES | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Legume flours** | | | | | | | | | | | | | |
| Red kidney bean flour | 23.32 | | 2.25 (g/g) | 1.52 (g/g) | 10 (%) | 0.556 | | 45.7 (mL/100 mL) | 41.2 (mL/100 mL) | 55.0 (mL/100 mL) | | 52.4 (mL/100 mL) | (Siddiq et al., 2010) |
| Small red kidney flour | 20.93 | | 2.65 (g/g) | 1.23 (g/g) | 10 (%) | 0.526 | | 38.2 (mL/100 mL) | 43.3 (mL/100 mL) | 60.5 (mL/100 mL) | | 62.3 (mL/100 mL) | (Siddiq et al., 2010) |
| Cranberry flour | 23.62 | | 2.41 (g/g) | 1.48 (g/g) | 12 (%) | 0.539 | | 49.6 (mL/100 mL) | 54.9 (mL/100 mL) | 53.4 (mL/100 mL) | | 52.4 (mL/100 mL) | (Siddiq et al., 2010) |
| Black bean flour | 23.24 | | 2.23 (g/g) | 1.34 (g/g) | 12 (%) | 0.515 | | 37.4 (mL/100 mL) | 39.4 (mL/100 mL) | 45.6 (mL/100 mL) | | 48.2 (mL/100 mL) | (Siddiq et al., 2010) |
| Yam bean flour | 20.43 | | 131.9 (%) | 0.6 (mL/g) | 14.3 (%) | | | 40.2 (%) | | 50.7 (%) | | | (Obatolu et al., 2007) |
| Green gram flour | NR | | 1226 (g/kg) | 900 (g/kg) | | 0.69 | | 16 (%) | | 48 (mL oil/g of sample) | 54.0 | 51.8 (%) | (Ghavidel & Prakash, 2006) |
| Bengal gram flour | NR | | 1362 (g/kg) | 788 (g/kg) | | 0.73 | | 12 (%) | | 185 (mL oil/g of sample) | 51.6 | 49.4 (%) | (Ghavidel & Prakash, 2006) |
| Pigeon pea flour | 22.4 | | 138 (%) | 89.7 (%) | 12% (w/v) | | | 68 (%) | 20 (%) | 49.4 (%) | | | (Oshodi & Ekperigin, 1989) |
| Cowpea flour | NR | | 1285 (g/kg) | 993 (g/kg) | | 0.65 | | 40 (%) | | 69 (mL oil/g of sample) | 51.9 | 50.1 (%) | (Ghavidel & Prakash, 2006) |
| Field pea flour | 25.0 | 80.3 (%) | 0.78 (g /g) | 0.41 (g oil/g sample) | | | | | | 34.6 (mL oil/0/1 g sample) | | | (Sosulski & McCurdy, 2006) |
| Lentil flour | NR | | 974 (g/kg) | 857 (g/kg) | | 0.85 | | 22 (%) | | 58 (mL oil/g of sample) | 50.5 | 48.1 (%) | (Ghavidel & Prakash, 2006) |
| Lentil flour | NR | | 3.20 (mL/g) | 0.95 (mL/g) | 8.0 (%) | 0.91 | | 40.0 (%) | | | 47.4 | | (Aguilera et al., 2009) |
| Desi chickpea flour | 20.6–24.3 | | 1.34–1.39 (g/g) | 1.05–1.17 (g/g) | 10–14 (%) | | | | | | 59.6–68.8 | 76.6–81.3 (%) | (Kaur and Singh, 2005) |
| Kabuli chickpea flour | 26.7 | | 1.33 (g/g) | 1.24 (g/g) | 10 (%) | | | | | | 58.2 | 82.1 (%) | (Kaur & Singh, 2005) |
| Chickpea flour | NR | | 2.10 (mL/g) | 1.10 (mL/g) | 8.0 (%) | 0.71 | | 24.0 (%) | | | 22.9 | | (Aguilera et al., 2009) |
| Faba bean flour | 29.2 | 85.9 (%) | 0.72 (g /g) | 0.47 (g oil/g sample) | | | | | | 34.6 (mL oil/0.1 g sample) | | | (Sosulski & McCurdy, 2006) |
| Peanut flour | 52.73 | | 1.67 (mL/g) | 2.67 (mL/g) | | | | 0.06 (mL/g) | | 87.08 (mL/g) | | | (Yu et al., 2007) |
| Soybean flour | 48.2 | 20.6 (%) | 1.75 (g/g) | 0.56 (g oil/g sample) | | | | | | 37.2 (mL oil/0.1 g sample) | | | (Sosulski & McCurdy, 2006) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Legume protein isolates** | | | | | | | | | | | | | |
| Field pea protein isolate | 80.3 | 38.1 (%) | 2.52 (g /g) | 0.98 (g oil/g sample) | | | | | | 36.6 (mL oil/0.1 g sample) | | | (Sosulski & McCurdy, 2006) |
| Faba bean protein isolate | 86.3 | 40.0 (%) | 2.16 (g /g) | 1.78 (g oil/g sample) | | | | | | 38.6 (mL oil/0.1 g sample) | | | (Sosulski & McCurdy, 2006) |
| Micelle chickpea protein isolate | 87.8 | 72.5 (%) | 4.9 (mL/g) | 2.0 (mL/g protein) | | | 43.3 (%) | | 59.2(%) | | 63.7 | 94.3 (%) | (Paredes-López et al., 2006) |
| Isoelectric chickpea protein isolate | 84.8 | 60.4 (%) | 2.4 (mL/g) | 1.7 (mL/g protein) | | | 47.5 (%) | | 66.6(%) | | 72.9 | 85.0 (%) | (Paredes-López et al., 2006) |
| Soybean protein isolate | 82.3 | 30.6 (%) | 2.65 (g /g) | 1.03 (g oil/g sample) | | | | | | 45.1 (mL oil/0.1 g sample) | | | (Sosulski & McCurdy, 2006) |
| Soybean protein isolate | NR | 21.2 (%) | 5.7 (mL/g) | 1.9 (mL/g protein) | | | 41.8 (%) | | 53.2(%) | | 50.8 | 99.7 (%) | (Paredes-López et al., 2006) |
| Soybean protein isolate | 90.2 | 22.2 (%) | 584 (%) | 144 (%) | | | | | | | 75.1 | | (Naczk et al., 1986) |
| Cowpea protein isolate | 95.7 | | 2.20 (mL/g) | 1.10 (mL/g) | 6 (%) | 0.82 | | | | | 50 | | (Ragab et al., 2004) |
| **Legume protein concentrates** | | | | | | | | | | | | | |
| Soybean protein concentrate | 69.6 | 31.5 (%) | 445 (%) | 157 (%) | | | | | | | 59.4 | | (Naczk et al., 1986) |
| Peanut protein concentrate | 77.82 | | 1.11 (mL/g) | 0.90 (mL/g) | | | | 0.02 (mL/g) | | 87.50 (mL/g) | | | (Yu et al., 2007) |
| *P. angularis* | 79.6 | | 5.05 (g/g) | 4.38 (g/g) | | | | 80.4–140.1 (%, pH 2–10) | | | 54.7–57.0 (pH 2–10) | 93.2–96.7 (%, pH 2–10) | (Chau et al., 1997) |
| *P. calcaratus* | 78.0 | | 5.28 (g/g) | 4.71 (g/g) | | | | 80.2–130.0 (%, pH 2–10) | | | 54.5–57.7 (pH 2–10) | 94.5–97.3 (%, pH 2–10) | (Chau et al., 1997) |
| *D. lablab* | 85.0 | | 5.08 (g/g) | 4.77 (g/g) | | | | 60.5–140.2 (%, pH 2–10) | | | 53.0–57.9 (pH 2–10) | 94.9–97.1 (%, pH 2–10) | (Chau et al., 1997) |
| Soybean protein concentrate | 78.7 | | 3.46 (g/g) | 3.06 (g/g) | | | | 50.8–100.2 (%, pH 2–10) | | | 54.5–58.1 (pH 2–10) | 94.6–97.8 (%, pH 2–10) | (Chau et al., 1997) |
| Pea protein concentrate | 55.5 | | 153.0 (%, V/W) | 113.0 (%, V/W) | | 0.45 | | | | | 22.4 | | (Conc & Blend, 1981) |

BD, bulk density; EA, emulsifying activity; EC, emulsifying capacity; ES, emulsifying stability; FAC, fat absorption capacity; FC, foaming capacity; FE, foaming expansion; FS, foaming stability; LGC, least gelation concentration; NR, not reported; PS, protein solubility; WHC, water-holding capacity.

and fat absorption capacity and gelling, foaming, and emulsifying. A comparison of the functional properties of different legume flours is provided in Table 14.3. Depending on the final particle size, ground flakes and seeds of oilseeds and pulses can be classified as medium, fine or coarse. Final particle size distribution of the flour can have an impact on ingredient functionality and thus should be kept in mind during processing.

Table 14.4 presents a list of some commercially available legume flour products in North America. One of the interesting products on the list is a fermented soybean powder prepared with non-genetically modified soybean, which is fermented with *L. acidophilus, Bifidobacterium* spp., *L. bulgaricus* and *S. thermophilus* prior to drying. Due to the reported health benefits of probiotic bacteria (e.g. reducing risks of gastrointestinal tract disease, colorectal cancer and constipation, as well as boosting the immune system) (Ouwehand et al., 2002), there is growing interest in North America in formulating foods containing probiotics. As shown in Table 14.4, the legume flour products presented are touted as being gluten free, and their high-protein and high-fiber characteristics are highlighted. Suggested application areas include bakery products, cereals, nutritional bars, pastas, soups, sauces, processed meat products, batters and breadings, confections, frostings, and fillings.

### 14.5.3 Protein concentrates and isolates

Proteins are essential components of food. The quality of many cereal proteins is improved by complementation with legume proteins due to the high concentration of the amino acid lysine in legumes, which is often limited in cereals. Among legumes, soybeans have a Protein Digestibility Amino Acid Score (PDCAAS) of 100%, making them equivalent to dairy and meat in their ability to meet the essential amino acid requirements of humans. Pulses have lower PDCAAS scores but when used in mixed diets, they help to improve the protein quality score of food (Table 14.5) (Boye et al., 2012). Attempts to balance animal and plant sources of protein in the diet have created a market for plant-based proteins.

Several processes have been developed to extract proteins from legume flours and flakes (Figures 14.3–14.5). The process for protein extraction is typically the same for all legumes and can be done either through dry processing or wet processing. Dry processing involves air classification after milling of the flours as described above. However, protein content of the flours is much lower than for wet extracted ingredients. Protein contents reported for enriched flour fractions obtained using air classification range from 40% to 62% (Aguilera et al., 1984; Elkowicz & Sosulski, 1982; Gujska & Khan, 1991).

Wet processing (see Figure 14.5) provides flours with higher protein contents than dry processing. The process typically involves pretreatment of the oilseed or pulse to remove fiber and fat and decrease the particle size of the seed for efficient extraction. The next step is an alkaline extraction to solubilize protein, followed by filtration to remove insoluble carbohydrate material. Protein extraction can also be done with water or under acidic conditions (Boye et al., 2010a, 2010b). After filtration, the liquid extract is subjected to isoelectric precipitation or membrane filtration. At the isoelectric point, there is no net charge on the proteins, which allows them to precipitate out of solution. Membrane separation takes advantage of the differences in the molecular weight of the proteins to separate them from other soluble components in the extract. During isoelectric precipitation, the precipitate obtained is removed by centrifugation or filtration, washed and dried to obtain the concentrate or isolate, depending on protein purity. For membrane separation, the retentate, which contains the desired protein material, may be subjected to further diafiltration to remove salts, followed by drying (Boye et al., 2010a, b).

Washing of flours with alcohol can alternatively be used to obtain protein concentrates. In this instance, aqueous alcohol is used to remove alcohol-soluble carbohydrates and other alcohol-soluble compounds (e.g. flavors) from the defatted materials, leaving behind a higher protein-containing meal (protein concentrate) that is subsequently desolventized and dried.

Protein concentrates generally contain lower amounts of protein (65%, dry weight basis, dwb) than protein isolates, which typically have >85% protein dwb (Boye et al., 2010b). This classification is loosely interpreted by scientists as can be seen from Table 14.3 which presents the composition and functional properties of a variety of legume protein isolates and concentrates. Functional characteristics exhibited by legume protein concentrate and isolates are similar to those of the flours and include water- and fat-holding capacity, gelling, emulsifying, and thickening. As shown in Table 14.3, specific properties vary depending on the type of legume and product. Table 14.6 further lists some protein products prepared from various legumes that are commercially available in North America.

**Table 14.4** Examples of commercial legume flour products in North America

| Company | Products | Composition (source of products) | Characteristics indicated | Suggested applications |
|---|---|---|---|---|
| Best Cooking Pulses, Inc.[1] (Canada) | Pea flour<br>Chickpea flour<br>Lentil flour<br>Beans flour | 100% flours are obtained by milling whole pulse seeds | Gluten free, low in fat, high in protein, fiber and micronutrients, and can improve the nutritional quality of cooked and baked goods | Baked goods, cereals, extruded snacks, nutrition bars, pasta, soups and sauces, and processed meat products |
| Diefenbaker Seed Processor Ltd.[2] (Canada) | Chickpea flour<br>Yellow pea flour | Chickpea flour is made from 100% pure Canadian chana dahl (yellow gram); yellow pea flour is derived from 100% Canadian yellow split peas which are ground to a superfine powder | Gluten-free products that can be used in many vegetarian and ethnic homes | Chickpea flour can be used to prepare onion bhajias, traditional potato and vegetable pakoras, desserts and battered dishes; yellow pea flour is traditionally used to thicken soups and stews |
| Parrheim Foods Inc.[3] (Canada) | Fiesta flour | Fiesta flour is a finely ground flour from yellow field pea (contains 67% starch and a minimum of 22% protein) | Gluten-free products that can be used in a wide variety of applications | Extruded snacks, batters (as a water-binding agent), and breading (either in the breading or di mix); baked goods and sauces (as a water control agent) |
| Golden Peanut Company[4] (USA) | Peanut flour | Natural roasted partially defatted flour made from high oleic US grade peanuts (available in either 12% or 28% fat levels in various roasted colors) | Gluten free, GMO free, peanut flour can be used to add texture, peanut flavor, aroma or protein to different food products | Confections, nutritional bars, baked goods, seasoning blends, frosting and fillings, sauces and dressings, baking mixes, and peanut spreads |
| Thebes Trade International[5] (Canada) | Textured soy flour | Flours are obtained by milling the whole soybean seeds | The flours can be used as raw materials for frozen, fast and vegetable foods | Can be used in a broad range of instant snacks, ready and convenience meals (meat and non-meat), and functional health foods, meat substitute, vegetarian foods |
| Now Foods Inc.[6] (USA) | NOW™ fermented soy powder | Prepared with non-GMO soybeans, and cultured with *L. acidophilus*, *Bifidobacterium* spp., *L. bulgaricus & S. thermophilus* | This product combines the nutritive value of soybeans with the benefits of fermentation; it offers a broader nutrient profile than traditional soybean products with higher content of isoflavones | Can be consumed as a dietary supplement by mixing 2 tablespoons (32 g) daily with water or beverage |

[1] Website for Best cooking Pulses Inc.: www.bestcookingpulses.com/
[2] Website for Diefenbaker seed processor Ltd.: www.dspdirect.ca/
[3] Website for Parrheim Foods Inc.: www.parrheimfoods.com/
[4] Website for Golden Peanut Company: www.goldenpeanut.com/
[5] Website for Thebes trade international: http://nova2000.en.gongchang.com/
[6] Website for Now Foods Inc.: www.nowfoods.com/

**Table 14.5** Protein Digestibility-Corrected Amino Acid Score (PDCAAS) for some legumes

| Food | Food processing | PDCAAS (%) reported | PDCAAS (%) recalculated using reference pattern for 1–2 yr child, and LAA[1] | PDCAAS (%) recalculated using reference pattern for 3–10 yr child, and LAA[2] | References |
|---|---|---|---|---|---|
| Black beans | Raw, ground | 72 | 69, Met + Cys | 75, Met + Cys | (Sarwar, 1997) |
| Chickpea | Defatted flour from seeds soaked, decorticated, and dried | 44 | 59, Met + Cys | 64, Met + Cys | (Tavano et al. 2008)[3] |
| Cowpea, var. Bechuana white | Whole grain flour, raw | 80 (not given) | 80 (not given) | 87 (Lys) | (Anyango et al., 2011) |
| Kidney bean, red, Canadian | Raw | 28 | 37 Met + Cys | 40 Met + Cys | (Khattab et al., 2009) |
| Lentil (*Lens culinaris*, cv. Medik) | Soaked 18 h; drained; autoclaved 10 min at 121 °C; cooled and freeze dried. Finely ground | 52 | (AA data not given) | | (Sarwar & Peace, 1986) |
| Pea (organic cultivation, 2002) | Cooked (and freeze-dried) | 75 | 82 Met + Cys | | (Jørgensen et al., 2008) |
| Peanut | Roasted in electric oven for 30 min at 140 °C and then ground | 70 | 65, Lys | 70, Lys | (Fernandes et al., 2010) |
| Soybean | Meal, raw | 80 | 88, Met + Cys | 96, Met + Cys | (Sarwar, 1997) |
| Cowpea, var. Bechuana white | Whole grain flour, raw | 80 (not given) | 80 (not given) | 87 (Lys) | (Anyango et al., 2011) |

Source: Boye et al. (2012).

PDCAAS recalculated using LAA and reference pattern for 1–2 yr child. Neither the AAS nor PDCAAS was truncated. A few studies had digestibility values for individual amino acids as well as for protein. In such cases, the protein digestibility value was used. Trp and His were not determined in some studies. In all the *in vivo* digestibility studies, the diet fed to animals was not the individual food item but included corn starch, sucrose, oil, vitamins, minerals, cellulose, etc.

[1] PDCAAS recalculated using LAA and reference pattern for 1–2 yr child (WHO, 2007).

[2] Diets included sucrose, fat, vitamins and minerals, fiber, choline bitartrate, and corn starch.

[3] LAA, L-aspartic acid; Lys, lysine; Met, methionine.

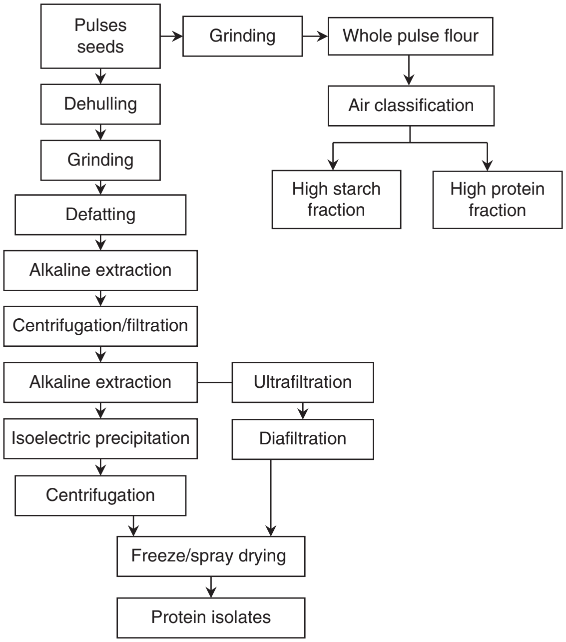


**Figure 14.3** Schematic diagram of wet and dry extraction processing of pulse proteins and other pulse fractions.

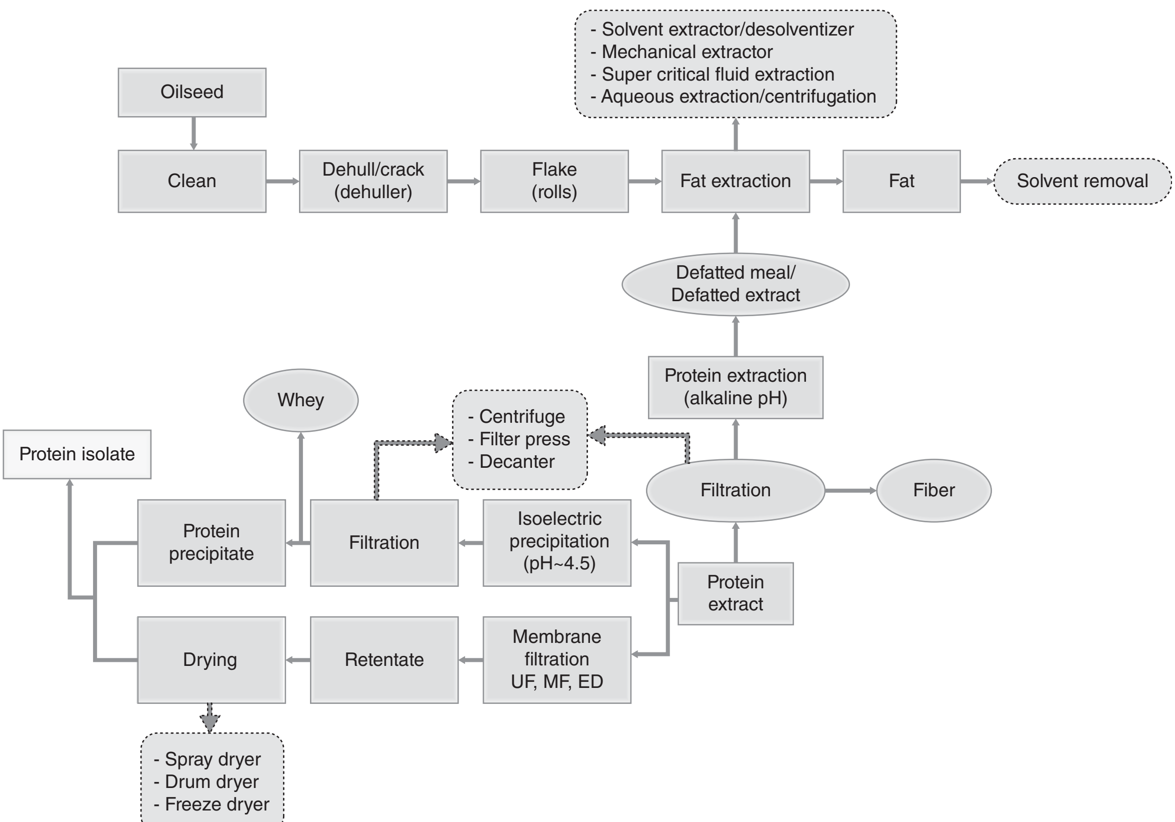


**Figure 14.4** Schematic flow diagram for the extraction of fat, fiber, and protein from oilseed legumes. ED, electrodialysis; MF, microfiltration; UF, ultrafiltration.

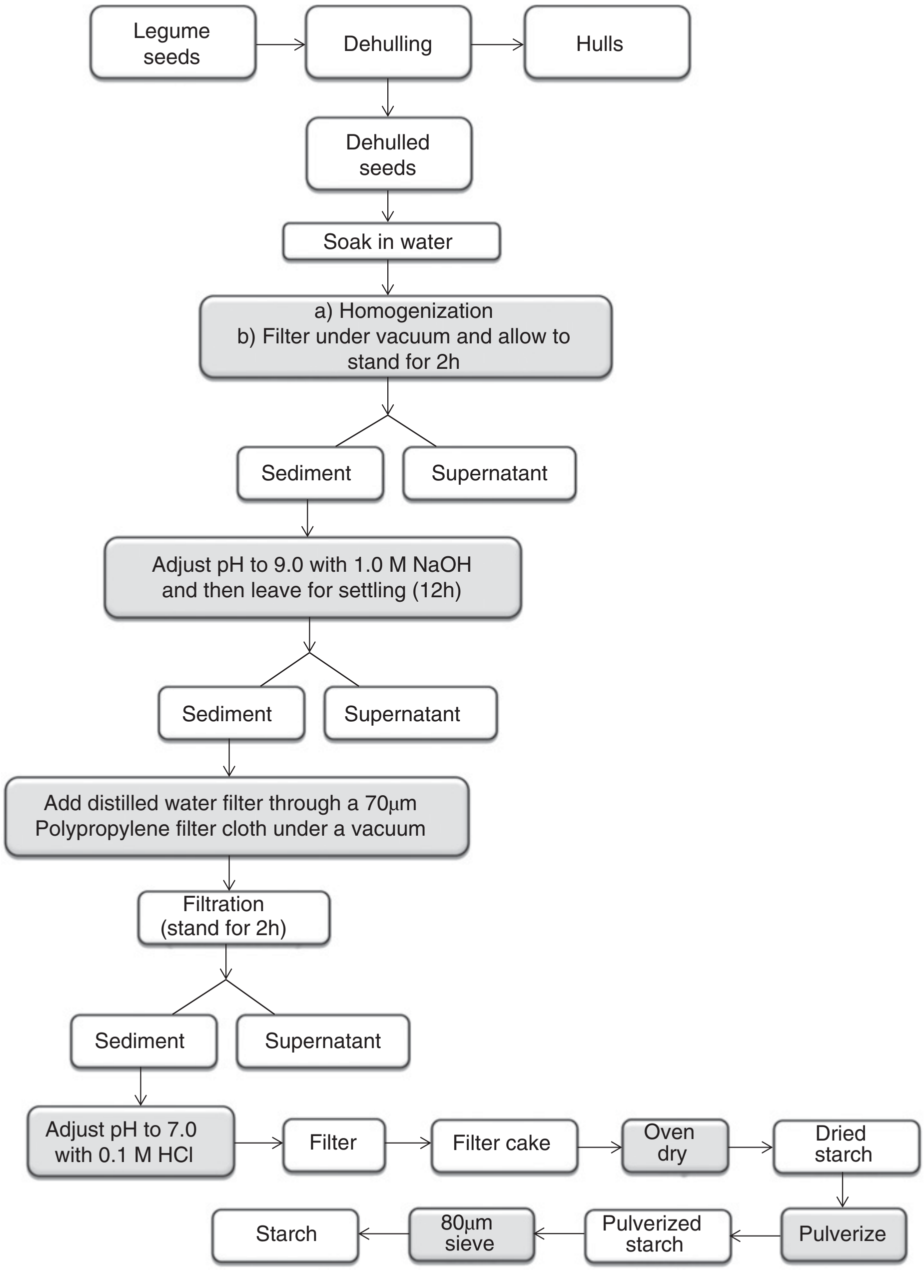


**Figure 14.5** Schematic flow diagram for starch preparation by wet milling of pulse seeds. Adapted from Hoover et al. (2010).

### 14.5.4 Starch flours and concentrates

The composition of starch in various legume flours and fractions is provided in Table 14.2. Whereas very little starch is found in soybeans (trace) (Keshun, 1997) and peanut (3–6%) (Isleib et al., 2004), starch represents a major component of pulse legumes (38–56%) (Maaroufi et al., 2000; Marconi et al., 2000; Sosulski & McCurdy, 1987). Hoover et al. (2010) provide a comprehensive review on the composition, molecular structure, processing, and properties of pulse starches.

**Table 14.6** Examples of commercial legume protein products produced in North America

| Company | Products | Composition (source of products) | Characteristics indicated | Suggested applications |
|---|---|---|---|---|
| Nutri-Pea Limited[1] (Canada) | Propulse™<br>Propulse N™ | A natural food-grade pea protein isolate (with protein content of 82%) | Offers a high level of functionality and nutrition (with an excellent amino acid profile, absent in gluten, lactose, cholesterol and antinutrients), can be used for protein enrichment | Beverage dry mix, nutritional bars, meal replacement beverages, baby food formulations, vegetarian applications, pasta, meat and seafood products, breads, dressings |
| Herbal Extracts Plus[2] (USA) | Soy capsule | 100% soybean standardized extract (10% isoflavones) | Each capsule contains 600 mg of the extracted materials, and provides protein-rich soybean in the diet which may aid in lowering the risk of heart disease | Take one to two pea fiber capsules, two to three times each day at mealtimes |
| Norben Company Inc.[3] (USA) | Pea protein<br>Soy protein concentrates<br>Soy protein isolates | Protein extracts from pea and soybeans | Could be used as supplements in various food products; offers both nutritional and functional characteristics | Pasta, beverage, breads, dressings |
| Parrheim Foods Inc.[4] (Canada) | Prestige protein | Prestige protein is pea protein concentrate derived from field pea which contains 50% protein | Excellent emulsification capacity, oil and water absorption and foaming capacity; excellent amino acid profile; gluten free and has a low allergenicity | Specialty feeds, aquaculture feeds, pet food and food recipes |
| Parrheim Foods Inc.[4] (Canada) | Propel protein | Propel protein is concentrated from the yellow field pea and contains 44% protein | GMO free with very low allergenicity | Aquaculture, poultry and young swine diets due to its lysine content |
| Parrheim Foods Inc.[4] (Canada) | Fababean protein<br>Progress protein<br>Great Northern bean protein | Fababean protein is prepared from faba beans; Progress protein is produced from the yellow or green field pea; Great Northern bean protein is produced from great northern beans | Non-GMO, low allergenic, gluten free, functional and natural; excellent and valuable ingredients in various food applications | Different food recipes |
| Now Foods Inc.[5] (USA) | NOW™ Sports Pea protein | 100% pure non-GMO pea protein isolates | Dietary supplement which is high in branched chain amino acids (each scoop contains over 4800 mg branched chain amino acids and over 2000 mg of L-arginine); has high solubility and is easy to digest | Mixe one scoop (33 g) of pea protein with 8 oz. of cold water, juice, or beverage and blend |

[1] Website for Nutri-pea Ltd.: www.nutripea.com/index.htm
[2] Website for Herbal Extracts Plus: www.herbalextractsplus.com/
[3] Website for Norben Company Inc.: www.norbencompany.com/
[4] Website for Parrheim Foods Inc.: www.parrheimfoods.com/
[5] Website for Now Foods Inc.: www.nowfoods.com/

As with proteins, pulse starches can be processed using either dry (air classification) or wet processing techniques. Figure 14.5 presents the process for wet milling of starch. Similar to the protein extraction process, starch purity is higher when processed by wet milling. The properties of legume starch vary depending on the ratios of amylose and amylopectin, the two major components of starch that determine starch functionality in food applications. Starches are of interest in food formulation as they provide texture through their rheological and swelling properties. High-amylose starches retrograde to a greater extent than high-amylopectin starches, resulting in increased degrees of crystallinity, syneresis, and gel firmness.

Table 14.7 provides a list of some of the important properties of legume starches. Although commercial applications have been limited due to the poor swelling power and dispersibility and high gelatinization temperature and water exudation of pulse starches (Hoover et al., 2010), there is technological and nutritional interest in pulse starches as they provide unique functional characteristics. From the nutritional perspective, there is interest in the high resistant starch (RS) content of some pulse flours, as RS has been linked with health benefits such as reduced risk of colon cancer and diabetes, and providing a substrate for growth of probioctic organisms (Boye & Ma, 2012; Hoover et al., 2010). A list of some of the commercial legume starch products available in North America, their characteristics and suggested applications is provided in Table 14.8 and Figure 14.1.

### 14.5.5 Fiber products

Legumes are a good source of dietary fiber (both soluble and insoluble). Insoluble fibers found in legumes include cellulose, hemicellulose and lignin, whereas soluble fibers comprise oligosaccharides such as stachyose, raffinose, verbascose, and pectin. Increased fiber consumption can reduce the risk of many diseases including heart disease, diabetes, obesity, and some forms of cancer (Marlett et al., 2002). Fibers also provide physicochemical functionality to foods through their ability to bind and hold liquids such as water and fat, their swelling properties, and their impact on product viscosity. In the recent past, there has been growing interest in the use of fibers in food formulation due to their beneficial properties.

Legume hulls are removed as one of the first steps in processing, and this provides a by-product that is rich in fiber and which can be used as an ingredient by food processors. As particle size of the final fiber product can influence its physicochemical properties (e.g. dispersibility, water absorption) and nutritional quality (e.g. role in colonic function, transit time, etc.) (Tosh & Yada, 2010), the technique used for milling needs to be carefully considered. The particle size of the hull fiber can be controlled by judicious selection of milling procedures and screens (Ngoddy et al., 1986). Additionally the composition of protein, fat, minerals, and carbohydrates in the final product will also affect functionality.

During wet extraction of proteins and starch, the fiber fraction is separated, and this by-product can be dried and milled for use as a value-added product (see Figures 14.1, 14.2). Perhaps the best known legume fiber product is okara, the by-product obtained during soymilk production. To prepare soymilk, soybeans are soaked in water, cooked, ground and filtered to obtain the smooth-textured soymilk. This leaves behind a residue, the okara, which contains the bulk of the soybean fiber. In addition to fiber, soy okara contains protein (32%), oil (15%), and ash (3%) (Espinosa-Martos & Rupérez, 2009), which makes it a promising nutritive ingredient that could be incorporated in functional high-fiber foods.

Legume fibers as prebiotics for the growing probiotic food market are particularly promising. Prebiotics are carbohydrate sources of food for probiotics. In addition to the indigestible oligosaccharides found in legumes, legume starches with high amounts of amylose, which resists enzymatic hydrolysis (also classified as resistant starch), can serve as prebiotics (Conway, 2001; Niba, 2002; Wollowski et al., 2001). Various researchers are studying the resistant starch characteristics of different legume fibers in order to identify market applications (Bravo et al., 1998; Cairns et al., 1996; Tovar & Melito, 1996). Table 14.9 provides a list of some of the commercial legume fiber products available, their characteristics, and suggested applications.

### 14.5.6 Nutraceutical products

In addition to the major components, legumes contain minor components that may have health benefits. Isoflavones from soybeans have been of particular interest due to their reported beneficial effects on menopausal symptoms. Isoflavones are naturally occurring polyphenolic compounds belonging to the phytoestrogen class. Twelve different types have been found, which include daidzin, genistin, glycitin, acetyldaidzin, acetylgenistin,

**Table 14.7** Properties of legume starches

| Legumes | Processing techniques | Yield (%) | Total amylose (%) | SP or SF[1] | Pasting temp. (°C) | $T_o$ (°C)[2] | $T_p$ (°C)[2] | $T_c$ (°C)[2] | Crystallinity (%) | ΔH | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Kabuli chickpea | Soaking with $H_2O$ containing 0.2% sodium hydrogen sulfite, dehulling, grinding, filtering with 100-mesh sieve and centrifuging, then washing sediment repeatedly with water | 37.94 | 31.8 | 11.61 SP (g/g) | 73.4 | 59.4 | 68.6 | 77.8 | 13.12 | 1.198 (J/g) | (Miao et al., 2009) |
| Desi chickpea | Same as the above | 29.65 | 35.24 | 13.3 SP (g/g) | 70.7 | 62.2 | 67.0 | 72.0 | 12.0 | 1.87 (J/g) | (Miao et al., 2009) |
| Black bean | Steeping in water containing 0.01% sodium metabisulfite, homogenizing and passing through a 202 screen, residue was homogenized and passed through a 70 μm screen, filtrate was left standing for sedimentation. Sediment was suspended in 0.2 NaOH and left standing and the final sediment was suspended in water and passed through a 70 μm screen, neutralized and then dried | 16.37–21.80 | 37.17–39.32 | 8.2–17.7 SF (v/v) | | 61.0–65.7 | 70.9–74.9 | 81.2–86.7 | 32.1–32.7 | 17.8–20.1 ΔH /AP[3] (mJ/mg) | (Zhou et al., 2004) |
| Pinto bean | Same as above | 25.01–28.25 | 31.34–31.93 | 9.9–10.4 SF (v/v) | | 63.3–64.5 | 70.9–76.5 | 85.1–88.8 | 33.0–33.4 | 17.9–18.8 ΔH /AP[3] (mJ/mg) | (Zhou et al., 2004) |
| Lentil | Same as above | 27.44–34.07 | 30.51–32.29 | 16.0–18.4 SF (v/v) | | 60.0–60.1 | 66.0–66.6 | 76.4–77.5 | 31.7–32.3 | 15.5–16.6 ΔH /AP[3] (mJ/mg) | (Zhou et al., 2004) |

(*Continued*)

**Table 14.7** (*Continued*)

| Legumes | Processing techniques | Yield (%) | Total amylose (%) | SP or SF[1] | Pasting temp. (°C) | $T_o$ (°C)[2] | $T_p$ (°C)[2] | $T_c$ (°C)[2] | Crystallinity (%) | ΔH | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Smooth pea | Same as above | 19.40–28.90 | 34.73–35.09 | 16.2–16.6 SF (v/v) | | 61.1–63.9 | 67.7–70.6 | 77.3–80.1 | 30.0–30.3 | 14.6–16.3 ΔH /AP[3] (mJ/mg) | (Zhou et al., 2004) |
| Wrinkled pea | Same as above | 21.60 | 78.42 | 3.4 SF (v/v) | NR | NR | NR | NR | 17.7 | NR | (Zhou et al., 2004) |
| Chickpea | Steeping in water containing 0.16% sodium hydrogen sulfite, grinding and screening through 100-mesh, centrifuging the filtrating slurry after removing supernatant, drying | 29.0–35.2 | 28.6–34.3 | 11.4–13.6 SP (g/g) | 75.4–76.7 | 61.5–64.8 | 66.7–69.0 | 71.3–73.8 | NR | 7.6–8.7 (J/g) | (Singh et al., 2005) |
| Soybean | Blending in 0.3% sodium metabisulfite, filtering through a screen of 106 μm mesh and centrifuging, the sediment was washed with 10% toluene in NaCl and left standing; sediment was then washed with water and filtered | NR | 11.8–16.2 | NR | 71.6–83.8 | 52.0–53.5 | 56.5–57.9 | NR | NR | 12.3–12.9 (J/g) | (Stevenson et al., 2006) |
| Soybean | Same as above | NR | 16.5–19.8 | NR | 68.9–82.4 | 51.2–51.8 | 55.2–55.8 | NR | NR | 10.7–12.7 (J/g) | (Stevenson et al., 2007) |
| **Range** | | 16.37–37.94 | 11.8–78.42 | 8.2–16.6 | 68.9–83.8 | 51.2–65.7 | 55.2–76.5 | 71.3–88.8 | 12.0–33.4 | | |

[1] SP represents swelling power which is the ratio of the wet weight of the sedimented gel to its dry weight; SF represents swelling factor which is the ratio of the volume of sedimented gel to the volume of the dry starch granules with a density of 1.4 g/mL.
[2] $T_o$, $T_p$, $T_c$ indicate the onset, peak and end temperature of gelatinization, respectively.
[3] Gelatinization enthalpy (mJ/mg)/amylopectin content.
NR, not reported.

**Table 14.8** Examples of commercial legume starch products in North America

| Company | Products | Composition (source of products) | Characteristics indicated | Suggested applications |
|---|---|---|---|---|
| Nutri-Pea Limited[1] (Canada) | Accu-Gel™ | A food-grade, native pulse starch | Its superior gelling properties allow it to be used at a 20–30% lower usage level. It offers good body and mouthfeel without altering flavor | Oriental noodles, french fry batters and coatings, surimi, extrusion applications, low-cost meat formulations, fat-free sour cream, vegetarian applications, canned products, fruit fillings, and sauces |
| Parrheim Foods Inc.[3] (Canada) | Starlite™ | A pea starch concentrate derived from yellow field pea, which contains 85% starch (db) with a blend of 6% protein | Starlite expands well during extrusion<br>The use of Starlite in various food applications can increase resistant starch and slowly digestible starch content of the finished product; it can also improve moistness and water retention | Snack foods and breakfast cereals, noodle, pasta and baking recipes, making of bean-thread vermicelli |
| Parrheim Foods Inc.[2] (Canada) | Probond Starch | A blend of pea starch and pea protein | Can be used as a binding agent; produces a solid pellet and improves pelleting and extruding functions | Uses range from nutritional petfood recipes to the most rugged industrial binding application |
| Now Foods Inc.[3] (USA) | NOW™ PHASE 2™ starch neutralizer | A natural white kidney bean starch extract, also contains cellulose, cellulose powder and gum acacia | Product shown in non-clinical studies to help reduce the breakdown and absorption of complex carbohydrates, by limiting the action of α-amylase | Could be consumed as a dietary supplement by taking before any meal containing complex carbohydrates or starches |

[1] Website for Nutri-pea Ltd. : http://www.nutripea.com/index.htm;
[2] Website for Parrheim Foods Inc.: http://www.parrheimfoods.com/
[3] Website for Now Foods Inc.: http://www.nowfoods.com/

acetylglycitin, malonyldaidzin, malonylgenistin, and malonylglycitin. Some companies have developed processes to extract soybean isoflavones for nutraceutical and functional food applications, as shown in Table 14.10. Other microcomponents in legumes of growing interest are saponins, lectins, amylase, and protease inhibitors due to their reported benefits in decreasing risks of a variety of diseases including cardiovascular disease, diabetes, obesity, and cancer (Campos-Vega et al., 2010).

## 14.6 Novel applications

The use of legumes in food product formulations in North America has been made easier with the advent of technologies that have allowed novel convenient ingredients to be developed. Soybeans led this growth, with the expansion of novel product formulation in the last two decades. Figure 14.2 lists some of the soybean foods and products available today. A similar growth is occurring with pulse

**Table 14.9** Examples of commercial fiber products prepared from legume

| Company | Products | Composition (source of products) | Characteristics indicated | Suggested applications |
|---|---|---|---|---|
| Herbal Extracts Plus[1] (USA) | Pea fiber capsule | 100% pea fiber botanical powder | Each capsule contains approximately 600 mg of powdered pea fiber material; the bulking action of pea fiber may help to provide many healthful benefits | One to two pea fiber capsules, two to three times each day at mealtimes |
| Euringus Ingredients[2] (France) | Organic pea fiber | Contains insoluble dietary fiber from pea | Bringing many health benefits (such as reducing risk of colon cancer and coronary heart disease and cholesterol-lowering effects) as well as functionality (such as texture improver, fat replacer, and texture modifier) when supplementing organic pea fiber products into various food applications | Bread products (8–12% substitution); fiber additive (substitute for wheat, oat); meat products (sausage, beefburgers); meat products filler (by replacing starch); cookies and muffins (up to 25% substitution for flours); energy, health and wellness bars; noodles (3–5% substitution for wheat flours) |
| Best Cooking Pulses Inc.[3] (Canada) | Pea fiber | 100% pea fiber | Product is approved by Health Canada's Bureau of Nutritional Science, the FDA and the USDA | Health drinks, baked goods, cereals, extruded snacks, nutrition bars |
| Parrheim Foods Inc.[4] (Canada) | Exlite fiber | Concentrated from yellow field pea | A functional fiber (soluble and insoluble), high in fiber and mineral content (Fe and Ca); product made without any chemical extraction or modification; finely ground and tasty | Breads, rolls, muffins, cookies, breakfast cereals, pasta products, snack foods, and specialty health foods and beverages; Exlite can also be used to substitute (up to 25%) for wheat flour in cookies, cakes, and muffins |
| Nutri-Pea Limited[5] (Canada) | Uptake 80™ | A food-grade vegetable fiber | Offering both nutrition (fiber enrichment) and functionality (bulking agent and texture modifier) due to its high level of soluble and insoluble fiber, with high water-binding capacity | Low-fat and fat-free applications, hamburgers, veggie burgers and wieners, sauces and fillings, nutritional bars, cookies and brownies, processed fish products |
| Nutri-Pea Limited[5] (Canada) | Centu-Tex™ | A food-grade vegetable fiber | Offering similar benefits as for Uptake 80™ with added benefit of a higher water- and fat-binding capacity | Low-fat and fat-free applications, hamburgers, veggie burgers and wieners, sauces and fillings, nutritional bars, cookies and brownies, processed fish products |

(*Continued*)

Table 14.9 (*Continued*)

| Company | Products | Composition (source of products) | Characteristics indicated | Suggested applications |
|---|---|---|---|---|
| Nutri-Pea Limited[5] (Canada) | Centara III™ Centara IV™ Centara 5™ | A natural food-grade vegetable fiber manufactured from the hulls of Canadian yellow peas | Offering an excellent means of insoluble fiber fortification without significant alteration in color, flavor or odor. Centara IV and 5 are progressively whiter in color and are particularly suited for color-sensitive applications | Nutritional bars, white breads, bagels, tortillas, pasta, vegetarian applications, cookies and crackers |
| Golden Peanut Company[6] (USA) | AgForm 100 AgForm ES AG Granules Granules ES | Made from peanut hull and fiber | An excellent source of cellulose and crude fiber, peanut hulls are high in liquid absorbency, and have chemical inertness and biodegradability | Peanut hull and fiber products are primarily used in animal feed, as pesticide and fertilizer carriers, and as industrial absorbents; other uses include fiber ingredient, cellulosic products, fiber filler products, extender products, composite products, and inert carrier products |

[1] Website for Herbal extracts plus: www.herbalextractsplus.com/
[2] Website for Euringus Ingredients: www.euringus.com/
[3] Website for Best cooking Pulses Inc.: www.bestcookingpulses.com/
[4] Website for Parrheim Foods Inc.: www.parrheimfoods.com/
[5] Website for Nutri-pea Limited: www.nutripea.com/index.htm
[6] Website for Golden Peanut Company: www.goldenpeanut.com

legumes as pulse flours, protein, starch and fiber fractions become increasingly available. A list of some of the potential and current applications of legume flours and fractions including pulses is presented in Figure 14.1.

## 14.7 Conclusion

Socio-economic, environmental and population challenges will likely continue to exert pressures on food prices and food supply in the coming decades, which will have impacts on global food security and the environment. Legumes are important sources of protein, carbohydrate and oil and other critical micronutrients. Maximizing their benefits as integral components of the global food supply requires the following: (a) agricultural technologies to enhance their production; (b) primary processing technologies to minimize losses during harvest and post harvest; and (c) effective techniques for their secondary and tertiary processing to expand convenience and ease of use. Currently, legumes are used as whole foods and as ingredients in food formulation. Growth in the sector has resulted from robust research over many years. Whereas much progress has been made with soybeans, there remains room for innovation, especially with regard to pulse legumes. For oilseed legumes, specifically soybeans and peanuts, research on ways to reduce allergenicity in order to expand their consumption will be useful. Legume processing is one of the most important activities in the food industry and results in a large variety of products with unique properties. The processing of legumes makes them acceptable to consumers. Both traditional and modern methods of processing legumes result in products that are suited for different purposes so both avenues should be exploited.

**Table 14.10** Examples of commercial products prepared from micronutrients in soybean

| Company | Products | Composition (source of products) | Characteristics | Suggested applications |
|---|---|---|---|---|
| Now Foods Inc.[1] (USA) | NOW™ Extra Strength Soy Isoflavones Vcaps™ | Soybean extracts and other ingredients including rice flour, cellulose, silica and magnesium stearate | Product extracted through a proprietary process that results in the highest natural levels of genistein | Could be used as a dietary supplement by taking one Vcaps one to three times daily |
| SISU[2] (Canada) | Soy Isoflavones | Soybean extract, standardized to contain 20% total isoflavones (genistein, daidzein and glycitein), also contains microcrystalline cellulose, magnesium stearate | Does not have estrogenic effect; product can alleviate menopause symptoms such as hot flashes; contains antioxidant that reduces free radicals that cause tissue damage | Suitable for vegans and contains no ingredients that are a source of gluten |
| Webber Naturals®[3] (Canada) | Webber Naturals® Soy Isoflavone Complex | Each capsule contains 50 mg soybean (*Glycine max*) (bean extract) and 20 mg isoflavones (40%), as well as non-medicinal ingredients such as gelatin capsule (gelatin, purified water), microcrystalline cellulose, vegetable-grade magnesium stearate (lubricant) | Contains isoflavones as phytoestrogens (plant source estrogens) that help to reduce or eliminate menopausal hot flashes | Could be consumed by taking one capsule two to three times daily, or as directed by a physician |
| Natural Factors®[4] (Canada) | Soy Isoflavones Complex Capsules | Each capsule contains 50 mg soybean isoflavone extract, total isoflavones of 13.8 mg AIE (aglycone isoflavone equivalents), and genistein compounds of 2.2 mg AIE | Product contains naturally balanced isoflavones, genistein and daidzein. These well-known flavonoids are complemented by other healthful natural compounds found in soybeans and soy foods. Provides support for menopausal symptoms and may slow bone density and inhibit bone reabsorption | Recommended to consume six capsules daily |

[1] Website for Now Foods Inc.: www.nowfoods.com
[2] Website for Sisu: www.sisu.com/sisu
[3] Website for Webber Naturals: http://webbernaturals.com/caen
[4] Website for Natural Factors: http://naturalfactors.com/caen

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