Chapter 2
An Overview of Plant-Based Protein Rich Products

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1 Introduction

Plant proteins have received much attention as highly nutritious and sustainable source of essential amino acids in the past two decades (Lonnie and Johnstone 2020; Sá et al. 2020). Plant-based proteins are consumed as alternative sources of protein among underdeveloped nations where animal-based proteins are either expensive or scarce. In developed countries, plant protein sources represent a core component of routine diet particularly in vegan foods. Moreover, plant protein sources are naturally embraced with biologically active food components and generally low in saturated fats (Hever and Cronise 2017) making them popular among health-conscious consumer groups.

The worldwide market value of plant proteins was estimated around US$ 12.1 billion in 2019 and this consumption pattern is predicted to surpass US$35.54 billion in 2024 (Wood 2020). The continued increasing demand and drive towards plant proteins consumption have been influenced by different factors including health-related problems such as animal protein sensitivities, saturated fats, trans

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fats, milk hormones, ethical and environmental concerns from some consumer groups, and beneficial health claims linked to plant-protein based diets (Lonnie et al. 2020; Malekinejad and Rezabakhsh 2015; Rangel et al. 2016; Rotz et al. 2010).

Several plant proteins sources such as wheat, rice, sorghum, millets, quinoa, soybean, pulses, seeds and nuts have been extensively explored and utilized as cost-effective and sustainable sources of protein – energy. Protein is an essential macronutrient and its regular supply through a variety of dietary sources is mandated for proper growth, development, and health maintenance (Burd et al. 2019). The nutritive value of dietary proteins varies depending upon their source, extraction methods, proteins purity, amino acid profile, digestibility, bioavailability and anti-nutritional factors (Mattila et al. 2018; Herreman et al. 2020). Proteins from plant origin are often regarded as nutritionally incomplete or inferior to animal proteins. However, existing set of knowledge provokes intelligent exploitation of plant proteins by consuming a variety of plant protein sources. Such a combination of varied plant protein sources in daily diet ensures a balanced supply of essential and non-essential amino acids to meet human physiological needs (López et al. 2018; Naghshi et al. 2020; Sá et al. 2020).

Proteins' structure represents their functional and technological properties under different set of food processing conditions (Loveday 2019). Animal proteins are more organized and form fibrillar or fibrous structure while plants contain less organized globular proteins. Such a structural variation results in differences in functional properties such as gelation, viscosity, water/fat retention, foaming capacity, emulsion stability, and matrix formation (Ismail et al. 2020). Moreover, cost-effective plant protein such as soy, chickpea, wheat, millet, barley proteins are also used as a base ingredient in formulating dairy alternatives (Dupont et al. 2020), meat analogues (Kyriakopoulou et al. 2019) and comminuted meat products (Youssef and Barbut 2011). In addition, textural attributes of plant proteins enable them to be shaped in a variety of products like tofu, tempeh, edamame, hummus, seitan, Ezekiel bread, cereal flakes and snacks etc. (Reynaud et al. 2021; Lambrecht et al. 2018; Fukushima 2011). Plant proteins not merely attribute textural and functional properties to the edible goods but also improve protein contents and overall nutritional quality.

A plethora of research has been performed in the last two decades on extraction of plant proteins and their food features in different food formulations (Fasolin et al. 2019; Sá et al. 2020). This chapter provides a comprehensive overview of plant protein – based products, traditional and commercial applications of plant proteins, novel applications of plant proteins in developing edible packaging, and plant proteins isolates and concentrates as potential therapeutic solutions for protein – energy malnutrition.

2 Plant-Based Protein Rich Products

2.1 *Grains Protein-Based Products*

2.1.1 Wheat Protein

Wheat (*Triticum aestivum*) is a cereal grain widely cultivated as a staple food over the globe. Worldwide, annual consumption of wheat was recorded 751.5 million metric tons in 2019 with an increasing demand driven by population growth, urbanization, economic development and changing lifestyles (Statista 2020). Wheat is a dominant and ubiquitous cereal crop used in several food products formulation such as bread, pasta, cake, nutritional bars and as meat analogs. A major proportion of wheat is annually converted into wheat starch and protein with approximately 1,270,000 tons production of wheat gluten (Markets and Research 2020). Wheat grain holds a variety of proteins which are differentiated by their solubility and structure such as monomeric or polymeric. The monomeric proteins include albumins (water soluble), globulins (salt soluble), and gliadins (alcohol soluble) while polymeric proteins are mainly insoluble glutenins (Thierry and Larbi 2018).

Wheat gluten is an insoluble functional protein extracted from wheat flour in wet form (gum gluten), which is dried into free-flowing bland tasting protein powder. Gluten proteins, which include gliadins and glutenins constitute 75–80% of the wheat proteins. When gluten protein is isolated from wheat flour, albumins and globulins (soluble proteins) are mostly washed out with starch (MacRitchie and Lafiandra 1997). Gluten exhibits tremendous structural and functional properties including extensibility, strong hygroscopicity, liposuction emulsification and thermosetting adhesion (Ortolan and Steel 2017). These functional characteristics make wheat gluten a valuable ingredient for the baking industry and extruded products.

Viscoelastic properties of gluten and their ability to bind water mandate gluten as a core ingredient for the baking industry. Vital wheat gluten supplementation (protein contents ≥80%) is recommended in bread to improve softness, elastic texture, yield and shelf life of the bread. Gluten enables bread dough to form continuous viscoelastic film to entrap gas produced during fermentation and baking of bread that favorably increase final bread volume and brings soft texture to the crumb (Rathnayake et al. 2018; Flambeau et al. 2017).

Gluten supplementation in products like pasta and spaghetti reduces product stickiness. Gluten protein is also used in formulating extruded breakfast products as well as 30% wheat protein enriched cereal flakes (Delcour et al. 2012). Furthermore, gluten protein is used as a binding material in coating batters of fried food products such as crumbed meat and nuggets (Dogan et al. 2005; Kumar et al. 2012). Other than its uses in bakery products, wheat gluten has limited applications due to its insolubility and viscoelastic nature. Product hydrolysis catalyzed by enzymes or acids results in loss of viscoelastic property of the protein. Hydrolyzed wheat gluten is used in the preparation of various liquid foods for protein enrichment such as dairy products (milk, yogurt and ice cream), high-protein sports beverages, soups and many other foods. In addition, hydrolyzed wheat protein present foaming and emulsification properties and is used as alternative to caseinates in numerous food applications such as in confectionary and non-dairy creamers (Flambeau et al. 2017) (Table 2.1).

Texturized Wheat Protein

A variety of plant-based meat alternatives have been developed that represent modest form of pure plant proteins products e.g. seitan, meat extender, flakes, snacks. Seitan is a traditional meat substitute formulated by monks in China as an alternate to duck meat. Seitan is composed of wheat protein extracted from wheat flour and then cooked in a soup or fried in oil. The main limitation to widen seitan consumption is linked to its slightly soft and sticky texture. However, the processing of seitan in vegetable soup or oil allows incorporation of spices and flavoring compounds which improve product taste (Jacobs 1994; Marcincakova et al. 2004; Mal'a et al. 2010).

Texturized wheat protein is developed at high shear, high temperature and low moisture conditions in an extruder. Treatment of wheat protein at high shear and temperature dissociate and uncoil the macromolecules of wheat protein which bring them to rearrange and crosslink through specific linkages in an oriented pattern. On exiting from the extruder dye, surface water of extrudate evaporates which renders the structure of product somewhat spongy. Akdogan (1999) reviewed a high moisture (above 60%) extrusion process to avoid spongy structure of the texturized wheat protein. During cooling step (below 100 °C), a shear flow of melted protein in dye converts the product into a thick-layered fibrous structure that is quite identical to meat analogs. Texturized wheat proteins are used in ready to serve meals applications as meat extenders (Samard et al. 2019) or in combination with heat-gelling proteins like egg white and soy isolates (Lambrecht et al. 2017).

2.1.2 Rice Protein

Rice (*Oryza sativa*) was lauded as "gold of the Orient" in ancient times and is the most common daily staple consumed by nearly half of the world population (Roy and Shil 2020). The worldwide average per capita rice consumption was close to ~54 kg/year in 2017, while its consumption exceeded 100 kg/year per capita in many Asian countries (FAO 2017). Rice has around 20% share in worldwide human caloric intake and anticipate upto 16% of the daily protein requirements making it most important cereal crop for human nutrition next to wheat (Awika 2011; Hoogenkamp et al. 2017). A major segment of global population consume rice in the form of whole or broken kernel. However, the known nutritional benefits and hypoallergenic properties of rice proteins have fueled the demand for formulating a range of rice protein-based products. Rice proteins mostly finds applications in infant formulas and gluten free value-added products (Amagliani et al. 2017).

Table 2.1 Application of wheat proteins in food products

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Vital wheat gluten	Above 80%	4–6%	White pan bread enriched with 10% resistance starch	Addition of vital wheat gluten improved loaf volume of the bread, reduced crust hardness and baking loss.	Kim et al. (2013)
Vital wheat gluten	Above 80%	8%	Brown rice pasta	Vital gluten incorporation improved palatability and cooking quality of brown rice pasta.	Kaur et al. (2017)
Wheat gluten	75–82%	10–18%	analogue meat nuggets	Cooking yield, general appearance, texture binding and overall acceptability of analogue meat nuggets enhanced with subsequent increase in levels of gluten protein.	Kumar et al. (2012)
Hydrolyzed gluten protein (HGP)	72–86%	5 g	Meringue	As foaming agent hydrolyzed gluten protein produced meringue batter with superior qualities (density and apparent viscosity) and after baking had greater specific volume than egg white protein containing meringue.	Wouters et al. (2018)
Wheat flour	12–13%	24–34%	Seitan	Wheat dough was washed repeatedly to remove starch and some bran. Obtained wheat gluten (seitan) was soaked in flavoring ingredients, coated with chickpea flour and fried in oil for 20 min. Overall nutritional quality and taste enhanced while cooking loss of seitan lowered after frying process.	Anwar and Ghadir (2019)
Wheat gluten	75–82%	8–14%	Noodle	Higher gluten content greatly reduced starch digestion rate and stickiness of cooked noodles while other texture attributes were comparable to control.	Yao et al. (2020)

(continued)

Table 2.1 (continued)

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Wheat gluten	75%	4%	Low fat beef sausages	Addition of wheat protein increased water holding capacity and emulsion stability of low-fat sausages without posing any detrimental effect on sensorial properties.	Serdaroglu and Ozsumer (2003)
Wheat gluten	78%	10%	Textured wheat protein	Gluten extruded under alkaline pH environment had improved textural attributes (elasticity, hardness and chewiness) and developed compact fibrous microstructure.	Li et al. (2018)

Rice kernel is rich in glutelin (60–80% of the seed protein) while considerable amount of albumin (4–22%), globulin (5–13%), and prolamin (1–5%) have also been reported by various researchers (Ju et al. 2001; Wang et al. 2014). Rice proteins are mostly crystalline and water-insoluble, however a substantial amount of protein found in rice bran are soluble in water and salted solutions.

The aleurone and sub-aleurone layers of rice grain stores most of the rice protein whereas more protein are expressed in the sub-aleurone layer. Rohrer and Siebenmorgen (2004) reported that longer milling time remove most of the protein bound to rice bran and results in a low level of protein contents in milled rice. Rice bran that contains germ and aleurone fractions deliver up to 15% (fat-rich form) and 18% (oil-free form) more protein contents as compared to the endosperm (Kahlon 2009; Fabian and Ju 2011). Since the rice kernel (endosperm) is low in protein contents, therefore, it may be regarded as an expensive starting material for protein rich products formulation. Contrarily, rice coproducts such as broken rice kernels, rice bran and the residues of rice starch extraction which have less economic value can serve as potential candidates for rice protein extraction (Hoogenkamp et al. 2017).

Broken rice being a plausible carrier of proteins (~8%) has also been used as the substrate to obtain rice protein by enzymatic degradation and removal of starch, and generating protein dense concentrates (~25% protein) and isolates (~90% protein) (Euber et al. 1991; Ahmadifard et al. 2016). During the process of rice syrup manufacturing, α-amylases help to liquefy starch granules and proteases enable protein to get released from fiber and starch granules. This process generates soluble rice protein concentrates with varying levels of protein contents and insoluble rice residue as coproducts of rice syrup. In a study by Shih and Daigle (2000), researchers used protein-containing coproduct (50% protein rich-residues) and formulated a rice protein-based product with 85% protein contents. Notably, protein bodies are tightly bonded on the surface of the starch granules; therefore, protease treatment or high-alkaline conditions are needed to release and purify rice proteins (Puchongkavarin et al. 2005). Rice proteins possess hypoallergenic properties; therefore, rice protein-based infant formulas (RPIF) are proposed for the dietary management of cow's milk protein allergy in infants (Vandenplas et al. 2014). Rice protein-based infant formulas are more specifically developed from rice protein concentrates, isolates or hydrolysates. As RPIF are strictly plant-based recipes, optimum nutritional composition of the food is ensured by fortification with limiting nutrients like lysine and threonine (Dupont et al. 2020).

Rice bran incorporation in meat batters anticipates good emulsifying and gelling properties to the product. In addition, fiber and protein components of bran bind and stabilize moisture and oil contents of products, thus providing textural stability to meat batters during freezing and thawing (Alauddina et al. 2017). Rice proteins have several commercial applications such as in nutritional supplements, confectionary, beverages and as flavor ingredient in savory products (Phongthai et al. 2017). Germinated brown-rice derived protein has Generally Recognized as Safe (GRAS) status, and has whey proteins bearing functional properties such as building and repairing of muscles (FDA 2015). Hypoallergenic and nutritional properties of rice protein products balance any shortcomings of the functional properties, thus making them competitive alternative plant-based protein products (Table 2.2).

2.1.3 Sorghum and Millets Protein

Sorghum (*Sorghum bicolor*) and millets are tropical cereals generally cultivated in Africa, Asia and in some regions of central America. Millets represents a group of several small cereal-grains species including finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), pearl millet (*Pennisetum glaucum*), proso millet (*Panicum miliaceum*) and teff (*Eragrostis tef*). Sorghum and millets are often considered together due to having same geographical distribution and matchable agronomic practices for cultivation (Taylor 2019). According to the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), around 600 million people in more than 30 countries depend on sorghum and millets as staple food crops (ICRISAT 2018). Sorghum and millet are gluten-free, rich in proteins, fibers and micronutrients (i.e., calcium and iron), and are indexed lower than wheat, rice and maize for glycemic response. Sorghum and millet based low to medium glycemic indexed foods are recommended for the dietary management of diabetes and celiac diseases (Kumar et al. 2018; Ciacci et al. 2007).

Sorghum and millets are mostly considered as "poor people's staple foods" contributing 8–15% of the daily protein requirements of the farming communities. The protein contents of these cereal grains vary considerably between species for example pearl millet contains protein-rich germ and deliver 14.5% protein. Contrarily, finger millet has relatively low (~8%) protein contents (Taylor and Taylor 2017). The major storage proteins of sorghum and millets are the endosperm-specific prolamins named kafirin and pennisetin, respectively. The other protein fractions are germ bound albumin and globulins while glutelins are concentrated in endosperm

Table 2.2 Application of rice proteins in food products

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Rice protein isolates (RPI)	91%	10%	Gluten free rice noodle	Combined application of RPI and transglutaminase (1%) increased viscosity, decreased cooking loss, cracks and water turbidity of rice noodle during cooking.	Kim et al. (2014)
Rice flour	6–8%	1.2–1.6%	Sponge and layer cakes	The finest rice flour (100 μm) gave viscous batter with lower specific volume and produced cakes having lower firmness and higher volume.	de la Hera et al. (2013)
Rice protein hydrolysates	78.2%	1.7–2%	Infant formula	Hydrolyzed rice protein formula enriched with lysine and threonine provided complete nutrition and well tolerated by infant allergic to cow milk protein.	Reche et al. (2010)
Broken rice protein	56–65%	2–9%	Sausages	Higher water holding, emulsifying and foaming capacity of broken rice protein significantly ($p < 0.05$) increased yield of sausages.	Hou et al. (2010)
Rice protein	79%	4% and 8%	Restructured beef steaks	Rice protein supplementation reassembled meat structure and increased availability of free amino acids with improved digestibility.	Baugreet et al. (2019)
Rice protein isolates	91%	3–12%	Meat extenders	Addition of RPI decreased cooking loss and increased water holding capacity of extended nuggets compared to control. All treatments involving RPI liked by panelists and showed high sensorial score.	Shoaib et al. (2018)

(continued)

Table 2.2 (continued)

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Brown rice protein isolates	80–90%	80–90%	Oryzatein	Protein sourced from whole rice grain providing all essential amino acids being used in multiple food grade products such as allergen free formulations, protein substitution in beverages and baked goods, confectionary, protein bars and as binder in savory meats beside cosmetics and nutraceuticals.	Janow (2018)
Rice protein isolates	92%	2.4 g	Maillard products	RPI glycated with glucose improved solubility, emulsification activity and emulsification stability of the Maillard reaction products	Li et al. (2009)
Rice protein extracts	–	0.5–10%	Brown rice beverage	Addition of rice protein extracts improved pasting properties, suspension and storage stability of brown rice beverage.	Nitisuk et al. (2019)

(Shewry 2002). Alike other cereals, sorghum and millets are deficient in lysine; however, they hold considerable amount of other essential amino acids (Joint FAO and WHO 2007). Millet storage protein (pennisetin) is far less studied than sorghum storage proteins (kafirin) but it is evident that both have similar amino acid composition regardless of differences in degree of polymerization or hydrophobicity (Taylor and Taylor 2017).

Sorghum and millets storage proteins (prolamins) differ substantially from those of wheat and other cereals and hence considered safe foods for individuals suffering from wheat allergy (Pontieri et al. 2013). Consumer food market has now been familiarized with gluten free food formulations. A variety of sorghum and millet based value-added baked goods, beverages and fermented products are now available in consumer market (Gull et al. 2014; Adebiyi et al. 2018). However, potential applications of pure proteins extracted from sorghum and millets are less documented with exception of the sorghum storage protein, kafirin (Taylor and Taylor 2017). Despite of its poor nutritional quality, sorghum kafirin has some unique functional attributes like high hydrophobicity, good alcoholic solubility, controlled morphology and the ability to self-assemble into biomaterials that give it commercial potential (Xiao et al. 2017) (Table 2.3).

Table 2.3 Application of Sorghum and millets proteins in food products

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Sorghum flour	11%	–	Pasta	Sorghum flour containing gluten-free pasta showed slower rate of starch digestion with high level of polyphenol contents and protein hydrolysis in simulated digestion.	Palavecino et al. (2019)
Sorghum Kafirin	83.6%	2%	Edible film	Application of kafirin containing edible coating on pears as a post-harvest treatment retarded respiration rate and progression of senescence during storage; however, was unable to prolong shelf life after 14 days of storage.	Buchner et al. (2011)
Sorghum Kafirin	–	750 mg	Encapsulating material	Catechin or sorghum condensed tannins (400 mg) containing kafirin microparticles showed no protein digestion but effectively released (50–70%) dietary antioxidants.	Taylor et al. (2009)
Pearl millet extruudates	9.6%	6.72%	Extruded supplementary foods	Millet flour (70%) blended with legumes flour (30%) to prepare extruded ready-to-eat foods. The high caloric supplement paste had viscous texture and improved carbohydrates digestibility being suitable for children and mothers.	Sumathi et al. (2007)
Germinated finger millet (finger millet malt)	7.81%	–	*Togwa* (Non-alcoholic beverage)	Addition of finger millet malt (source of amylase) in maize flour slurry (source of starch) cleared gel like consistency to viscous liquid and contributed sweet flavor.	Ndabikunze et al. (2001), Kitabatake et al. (2003)

(continued)

Table 2.3 (continued)

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Minor millets flour blends (barnyard, foxtail and kodo millets)	9–14%	–	Cookies	Gluten free cookies prepared from germinated minor millets flour blends were highly nutritious and were having acceptable textural properties.	Sharma et al. (2016)
Proso millet flour	12%	–	Gluten free pasta	Gluten free pasta was developed using proso millet as sole ingredient. Additionally, rheological and textural properties of pasta were improved by supplementing (1–2%) guar gum and xanthan gum.	Romero et al. (2017)
Pennisetin (Millet Protein)	95%	1.68 g	Casting biofilm	Pennisetin films casted from different plasticizers showed favorable mechanical and barrier properties comparable to other cereal proteins. However, their application as biofilm yet to be known.	Gillgren et al. (2011)

Kafirin Protein and Its Intended Uses

Kafirin protein is mainly extracted from industrial byproducts of milling, brewing, and bioethanol industry which reduce product cost, increase product demand and its consumption. Updates on use of kafirin at industrial scale promote its application as a functional protein in gluten-free formulations and value-added biomaterials (Husnain-Raza et al. 2017). Sorghum kafirin lacks viscoelastic properties like wheat-gluten which is a major drawback that limits its application in volume rising products (Schober et al. 2011). However, the inertness and hydrophobic nature of kafirin in aqueous environment benefits its application in high-value biodegradable biofilms synthesis. Giteru and his colleagues (2015) formulated kafirin based bioactive film loaded with plant essential oil citral and the polyphenol quercetin as bioactive packaging to maintain food quality and safety. It was found that Kafirin-citral films reduced the total viable microbial count and Kafirin-quercetin films inhibited lipid oxidation in fresh-chilled chicken fillets (Giteru et al. 2017). Kafirin could also be used as encapsulating agent for micronutrients and nutraceuticals. Condensed tannins from sorghum encapsulated with kafirin presented strong inhibitory effect against α-amylase and withstand simulated digestion showing potential to attenuate hyperglycaemia and control type 2 diabetes (Links et al. 2015).

2.1.4 Quinoa Proteins

Quinoa (*Chenopodium quinoa* wild) native to the Andes, is an annual herbaceous flowering plant primarily grown for its edible seeds (Jancurová et al. 2009). Quinoa is not a true cereal, but rather a dicotyledonous plant unlike most monocotyledonous cereals e.g., wheat, rice and barley (Mir et al. 2018). Quinoa is mainly cultivated in Peru, Bolivia, Chile and Ecuador representing 97% of world quinoa production (Balandrán-Quintana et al. 2019). Today, this plant has been introduced into different climatic regions because of its great ability to resist different agro-ecological conditions (Bazile et al. 2016). Quinoa is considered a complete food which deliver nutritionally well-balanced protein in terms of essential amino acids (López et al. 2018) and healthy lipids containing poly unsaturated fatty acids (PUFA i.e., linoleic and linolenic acids) (Altuna et al. 2018), desirable levels of vitamins and minerals, and other phytochemicals (Graf et al. 2015). Furthermore, quinoa protein is free from prolamin epitopes making it a safe candidate for formulating gluten free diets of celiac patients and those with wheat allergies (Vilcacundo and Hernández-Ledesma 2017).

Quinoa grains contain 14–18% protein contents encompassing a well-balanced amount of essential amino acids such as lysine, threonine and methionine (Gorinstein et al. 2002). Quinoa proteins mainly contain albumins and globulins, with little or no availability of prolamin proteins (Wang and Zhu 2016). Such a composition of quinoa proteins favors utilization of quinoa grains in developing protein-rich and gluten-free health advantageous products. Quinoa proteins have also good foaming capacity and hence can be used as functional ingredient in gluten-free baked and dairy recipes including bread, biscuits, pasta, crackers and milk (Deželak et al. 2014; Montemurro et al. 2019). Quinoa proteins lack viscoelastic properties which limit volume retention of the product during proofing and baking. Despite limited volume retention property, the addition of quinoa protein delivers quality attributes and mouth feel to gluten-free milk and other beverages (Abugoch et al. 2008). Furthermore, provided sufficient levels of essential amino acids meeting the criterion of FAO/WHO recommendations, quinoa proteins can also be suggested to formulate infant formulas (Vilcacundo and Hernández-Ledesma 2017). Some important functional properties like emulsification and structural gel matrix formation allow the use of quinoa protein in edible films packaging purposes. Quinoa protein-based films are reported to attribute antifungal properties which anticipate improved shelf stability of the consumer goods (Dakhili et al. 2019; Abugoch et al. 2011). Moreover, quinoa proteins are capable to hold flavors, add nutriture and bioactive components to foods and hence can be utilized in the fabrication of encapsulating material (Quintero et al. 2017; Zhu 2017) (Table 2.4).

Table 2.4 Application of quinoa proteins in food products

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Quinoa flour	16–18%	3.6%	Spaghetti	Quinoa addition increased net protein utilization, decreased true digestibility of starch and improved nutritional quality of corn-based spaghetti.	Giménez et al. (2016)
Quinoa grains	12.6%	5.0%	Cereal bar	Quinoa enriched cereal bar had high nutritional contents and acceptable functional parameters	Kaur et al. (2018)
Quinoa flour	16%	16%	Infant food	Feeding of quinoa-based supplementary food improved weight and plasma level of insulin-like growth factor-1 (IGF-1) in undernourished children.	Ruales et al. (2002)
Quinoa grains	16–18%	1.7%	Quinoa milk	Novel quinoa milk presented low glycemic index (52) and acceptable sensorial properties.	Pineli et al. (2015)
Whole or malted quinoa flour	16–18%	4.8–5.4%	Gluten free muffins	Addition of whole or malted quinoa flour to rice flour improved sensorial, textural and nutritive qualities of gluten free muffins.	Miranda-Villa et al. (2019)
Quinoa flour	16–18%	7.5 mg	Edible film	Strawberries coated with quinoa edible film inhibited yeast and mold growth and retained sensorial qualities.	Valenzuela et al. (2015)
Quinoa flour	16–18%	0.62%	Edible film	Coating of fresh blueberries with quinoa protein/chitosan/sunflower oil based edible film delayed fruit ripening and controlled growth of molds and yeasts during storage period of 32 days.	Abugoch et al. (2016)
Quinoa protein	–	10%	Encapsulating material	Use of quinoa protein as encapsulating agent of bioactive compounds (polyphenol and bixin) provided thermal stability and inhibited degradation of these compounds at high temperature.	Quiroz et al. (2020)

2.2 Legume's Protein

2.2.1 Soy Protein

Soybean (*Glycine max*) belongs to Fabaceae, the legume or pea family. Soybean is native to East Asia, widely distributed and grown in other continents for producing edible oil and protein rich products (Leamy et al. 2016). Soybean is naturally rich source of macronutrients such as high-quality protein (36%), soluble and insoluble carbohydrates (30%), fats (18%) and other plant nutrients including micronutrients (16%) (Thrane et al. 2017). Soy proteins deliver multiple nutritional and functional properties and have been used in the processing of many food products. In food industry, soy protein is supplemented with animal-based proteins such as eggs, poultry, meat, and dairy to enhance the protein quality of products. Moreover, soy proteins replacement with animal-based proteins reduces expense of food formulations and meets criterion of sustainable provision of good-quality protein in food supply chain (Riaz 2005; Singh et al. 2008). Soy proteins have multiple food applications in human nutrition such as processing of meat extenders (Carvalho et al. 2017), developing casein free infant formulas (Bhatia and Greer 2008), protein fortification (Rachman et al. 2019) and affordable plant-based milk alternatives development (Sethi et al. 2016) (Table 2.5).

Textured Soy Protein

Textured soy protein is used as a meat substitute in many meat products. Soy protein is replaced by 30–40% with meat in food products such as chicken nuggets and beef patties (Yeater et al. 2017). The soy protein substituted products have appearance and texture matchable to meat and meat products and provides high quality protein analog to that of lean meat. Textured soy protein has ability to be dyed using spices and malt extracts, and absorbs natural or synthetic flavors to increase sensorial properties of products. Notably, soy protein has excellent water holding capacity, therefore, soy protein substituted products remain soft by retaining more moisture during cooking, freezing, thawing and tolerate high temperature as compared to meat products made without supplementation of plant-based proteins (Thrane et al. 2017). Texturized soy protein can also be used in conventional food recipes as a substitute of meat-based protein. Omwamba et al. (2014) isolated texturized soy proteins from defatted soy flour and replaced meat at 25–100% levels as a protein source in samosa stuffing. Soy proteins supplementation in samosa significantly ($p < 0.05$) increased crude protein level and reduced fats contents and total calories (~24%) without damaging sensorial properties of product in comparison with 100% meat stuffed samosa (control). Additionally, oxidation of frying oil was also reduced in textured soy proteins stuffed samosa.

Table 2.5 Application of soy proteins in food products

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein content				
Soy protein isolates	90.07%	5–30%	Sponge Cake	SPI addition in cake batter at 20% improved nutritional quality and preserved quality of sponge cake.	Majzoobi et al. (2014)
Soy flour	38%	15.5–22.7%	Breakfast cereal	Soy-based high-protein breakfast cereal had increased nutritional contents and comparable acceptance ratings.	Yeu et al. (2008)
Soaked soybean	35.8%	1.2–3.2%	Soy milk	Soymilk displayed higher protein content and suits well as dairy alternative.	Kundu et al. (2018)
Soy protein isolates	91.5–92.2%	15%	Chiba tofu	Tofu prepared from SPI showed high hardness, springiness, and excellent quality.	Zheng et al. (2020)
Soy protein isolates	≥90%	15–25%	Sausages	Incorporation of SPI in buffalo meat improved texture, juiciness, and shelf-life of buffalo meat emulsion sausage	Ahmad et al. (2010)
Textured Soy protein concentrate	≥70%	10–40%	Nuggets (Meat extender)	Soy protein substituted nuggets had appearance and texture like meat-based nuggets.	Yeater et al. (2017)
Soy protein isolates	≥90%	4%	Coating powder	Coating powder formulated by using SPI had better water retention activity and solubility as compared to whey protein-based coating powder	Erdem and Kaya (2020)
Soy protein isolates	92%	2.5%	Encapsulating material	Encapsulation of fish oil in SPI/inulin composite film masked off-flavor and unpleasant odor of oil and showed stability against pH and thermal treatment.	Rios-Mera et al. (2019)
Soy protein isolates	90%	0.6 g	Biodegradable film	The biodegradable film prepared from SPI and poly lactic acid showed high transparency, strong adhesion, and markedly reduced water vapor permeability. Further this bilayer film loaded with natamycin, and thymol presented antifungal and antibacterial in *in-vitro* microbiological assays.	González and Igarzabal (2013)

Soy Protein Isolate

Soy protein isolate (SPI) is a highly purified form of soy protein extracted from defatted soy flour. SPI contains ~90% protein content on a dry weight basis and produces less flatulence than raw soy flour (Singh et al. 2008). SPI are mainly used in the food sector to enhance water retention, improve texture and protein contents of meat products, and as an emulsifier (Niu et al. 2017; Youssef and Barbut 2011). In a recent study, soy protein or whey protein isolates were mixed with sunflower oil using freeze drying technology to formulate coating powders (Erdem and Kaya 2020). The interaction between protein isolates and sunflower oil produced strong networks in formulated powders via hydrogen bonding. The coating powder formulated by using SPI had better water retention activity and solubility as compared to whey protein-based coating powder. It was worth noting that SPI supplemented coating powder was used in baked products and protected textural structure of sliced cake by its water retaining potential.

It has been observed that plant-based protein supplementation in meat emulsions prevent excessive tosses and deliver homogenous appearance to the product. Supporting this argument Youssef and Barbut (2011) reported that SPI supplementation (@12–14%) in meat protein batters improves emulsification by reducing meat protein aggregation and fat globules' agglomeration. Results from textural studies of SPI supplemented batters presented improved hardness and cohesiveness of the batters.

2.2.2 Pulse Proteins

Pulses are Leguminosae crops harvested solely as dry seeds. Pulses play an important role in sustainable and cost-effective supply of plant proteins. Because of their cost-effectiveness to meat and meat-based products, pulses are also claimed as "poor man's meat" in some countries (Shevkani et al. 2019). Pulses are a category of superfoods that include chickpeas (garbanzo beans), lentils (green, red, black, small, brown and French green), dry peas (split and whole) and beans (adzuki, black, kidney, pinto, fava, mung and lima beans). Pulses are nutrient dense foods characterized with high protein and fiber contents and relatively low fats contrary to the legumes like peanuts and soy. Protein contents vary considerably between different pulses based on genotypes, germination, fertilizers application and environmental stress during growth and development (Powers and Thavarajah 2019). Generally, pulses contain 20–30% protein contents concentrated as small spherical protein bodies in the seed cotyledons (Singh 2017). Pulse proteins are primarily composed of globulins (70–80%) and albumin (10–20%) while prolamin and glutelins are minor proteins accounting less than 5% (Gupta and Dhillon 1993). Pulse albumins are the most nutritious proteins in terms of amino acids profile. However, they may contain some anti-nutritional components like trypsin, hemagglutinins and amylase inhibitors which adversely affect their bioavailability (Bessada et al. 2019). The main functional proteins in pulses are globulins stored in the pulse seeds in the form of legumins and vicilins protein bodies. Based on amino acids composition of pulse proteins, legumins contain more sulfur-containing amino acids (cysteine and methionine) than vicilins (Robinson et al. 2019). The main advantage of pulse proteins over cereal proteins is that they are gluten free and rich in essential amino acids like lysine, thus, considered suitable in the diets of people living with gluten intolerance and celiac diseases (Mlyneková et al. 2014).

Pulse proteins find applications in multiple value-added and industrial products due to their low cost, wide acceptability, comparative functionality, high nutritional and nutraceutical properties (Klupšaitė and Juodeikienė 2015; Shevkani et al. 2019) (Table 2.6).

Pulse Protein Concentrates and Isolates

The purified pulse proteins as concentrates or isolates are typically used as nutritional additives and ingredients in novel and traditional food products. In addition to improving dietary protein quality, pulse proteins also contribute to improving sensorial properties of cereal-based foods. The addition of thermally modified i.e. denatured and glycated cowpea proteins in wheat flour improved water absorption during dough/batter formation and imparted soft texture to wheat bread and sponge cake. Additionally, it was also reported that replacement of whole egg with glycated cowpea protein @ 20% during batter formation did not affect sensorial acceptability of sponge cake (Campbell et al. 2016). In an attempt to develop B-saponins rich composite flour bread (Serventi et al. 2018), chickpea protein concentrate was partially substituted (one third) with soy blend for bread formulation. Incorporating chickpea in bread increased B-saponins levels as well as preserved bread loaf quality. Pulse proteins also improve textural properties of gluten-free products by the formation of viscoelastic protein networks in batters and dough systems (Shevkani et al. 2019). Protein isolates recovered from cowpeas, field peas, and kidney beans are being exploited for their possible application in gluten-free cupcakes and muffins. Kidney beans and pea protein isolates incorporation @10% level increased viscoelastic properties of corn starch-based batter and resulted in muffins with improved quality characteristics which include appearance, crust color, firmness, specific volume, cohesiveness, springiness and porosity (Shevkani and Singh 2014). The effect of chickpea protein isolates, transglutaminase and xanthan gum supplementation at various supplementation levels on quality and rheological attributes of millet muffins was evaluated by Shaabani et al. (2018) using the response surface methodology. Findings of the study suggested that textural qualities and formation of protein networks in gluten-free batter and muffins are possible to attain with the addition of chickpea proteins and transglutaminase.

Table 2.6 Application of pulse proteins in food products

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Broad-bean, yellow-pea and green-pea	11.5–18%	4.6–7.2%	Crackers	Pulse flour supplementation improved nutritional profile and eating quality of baked crackers.	Millar et al. (2017)
Chickpea protein concentrate (CPC)	64%	5–15%	Cereal foods (Cookies, pasta and fried corn snacks)	Quality and sensory attributes of cereal foods fortified with chickpea protein concentrate were not affected with subsequent increase in CPC content.	Yanez-Farias et al. (1999)
Pea protein isolates	86.99%	1–6%	Gluten free bread	Addition of pea protein positively influenced rheological and structural properties of gluten free dough.	Mariotti et al. (2009)
Pulse protein concentrate (chickpea, lentil and pea)	66.8%, 82.5% and 81.4%	3–9%	Bread	Wheat flour substitution with chickpea protein gave highest mass volume to bread and increased protein content.	Aider et al. (2012)
Lentil and white bean (protein extracts)	50.3% and 49.2%	3%	Sponge and pond cake	Lentil and white bean protein extracts application in baked products showed excellent foaming/emulsifying capacities, heat stability and gelling properties having potential to replace protein from animal origin.	Bildstein et al. (2008)
Chickpea, lentil, faba bean, mung bean, winged bean, pea and smooth pea (protein extracts)	~90%	2.3–3%	Bean curd (Dairy alternative)	Bean curds developed from chickpea and faba bean milk extracts had comparable quality and sensorial properties to soybean curd.	Cai et al. (2001)

(continued)

Table 2.6 (continued)

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Chickpea and lupin	19–36%	1–2.4%	Beverage (Milk alternative)	Chickpea and lupin protein addition optimized sensorial feature and provided stability to non-dairy alternative beverages	Lopes et al. (2020)
Chickpea protein concentrate	76.06%	1.5–5%	Merguez (Cooked sausages)	Chickpea protein improved process yield, protein content and color stability of sausage and also reduced cooking loss and lipid oxidation.	Ghribi et al. (2018)
Pea protein isolates	85.3%	3–12%	Meat extenders	Addition of pea protein isolates decreased cooking loss and increased water holding capacity of extended nuggets compared to control (100% chicken nuggets).	Shoaib et al. (2018)
Pea protein isolates	84.4%	0.5%	Encapsulating material	Microencapsulation of PUFA-rich oil in pea protein and pectin-based emulsion provided oxidative stability to oil.	Aberkane et al. (2014)
Chickpea protein isolates	88.1%	0.1 g	Encapsulating material	Chickpea protein showed effective loading capacity and provided stability to folate at various ranges of pH (2 to 8).	Ariyarathna and Karunaratne (2015)

Pulse Proteins Based Imitation Milk Products

Pulse proteins as concentrates or isolates are also explored in the preparation of imitation milks, beverages and bean curds. Protein isolates recovered from different pulses were used as protein source in the formulation of imitation milk and beverages (Sosulski et al. 1978). The pulses protein-based imitation milks were like as cow milk in color and viscosity but lower in taste and odor. The pulses were rated in the following increasing order of preferences for imitation milk formulation: faba bean<field pea<chickpea<lentils<lupine = northern peas<lima bean = mung bean = pea bean. Similarly, in another study by Cai et al. (2001) protein extracts from several pulses were applied in the development of bean curds. The authors reported that bean curds developed from chickpea and faba bean milk extracts (2.3–3% protein contents) using 1.5% CaSO4 as coagulant were best in terms of

quality and sensorial properties. Recently, Lopes et al. (2020) optimized sensorial features and stability of pulse beverages using different processing technologies which involved seed soaking, cooking with water, milling, sieving and beverage pasteurization. The milk beverages prepared by following these processing steps masked characteristic beany flavour and yielded protein contents 1.8–2.4% (w/v) in lupin beverage and 1.0–1.5% (w/v) in chickpea beverage. Marketing of such products target people allergic to cow and soy milk, older adults with poor appetite and difficulty in chewing and those prone to suffer from protein malnutrition.

Pulses Proteins-Based Comminuted Meat and Meat Analogs

Among various plant protein sources, pulses are famous candidates in meat products formulations as meat substitutes and binders to increase nutritional and textural properties (Pintado and Delgado-Pando 2020). In comminuted meat products, the starch, fiber and protein contents of pulses help to form complex gel networks and bind meat proteins. These protein networks further form strong bonds and entrap water or other compounds, thus facilitate to retain moisture in the meat matrix and prevent tosses during processing (Bassett et al. 2010). Additionally, the type and quantity of the pulse used, and the type of product also determine overall stability and water retention capacity of product. In this regard, Nagamallika et al. (2005) used Bengal gram and pea flour (levels of 5% and 10%) as meat substitute in patties. They reported that pea flour was more acceptable and yielded patties with higher emulsion stability and water holding capacity as compared to Bengal flour. Ghribi et al. (2018) investigated effect of chickpea protein concentrates supplementation at different levels (1.5–5% (w/w)) on the textural properties of raw and cooked sausages. Authors reported that chickpea protein not only improved process yield, protein contents and color stability of sausages but also reduced cooking loss and degree of lipid oxidation.

2.2.3 Peanut Protein

Peanut (*Arachis hypogaea* L.) is a leguminous crop of tropical and sub-tropical region that contains 16–36% high biological value protein contents. Peanuts are being accepted as functional food and extensively consumed as raw roasted, peanut butter, baked products, soup, confectionary and extender in meat analogue (Singh et al. 2021). Peanut proteins play an important role in developing various food products due to their nutritional value and for contributing special texture to food products (Shafiquer et al. 2018). Partially defatted flour of peanut is rich in protein contents and has been used in combination with other conventional flours to improve the nutritional value of the composite bread. Various other forms including peanut milk, peanut bar are also consumed in developing countries to combat protein energy malnutrition (Bansal and Kochhar 2013; Arya et al. 2016)

2.3 *Nuts Protein-Based Products*

Nuts are thick dried fruits and often contain hard shells that cover their edible kernel (Bewley et al. 2006). Nuts are healthier and nutrient-rich plant protein sources. Most nuts fulfil ~17% of daily protein requirements typically with 2–3 tablespoons (Freitas and Naves 2010). The best-known edible nuts include almond, walnut, Brazil nut, cashew nut, pistachio, hazelnut, chestnut and peanuts. Considerable scientific literature has elucidated consumption of nuts to hold cholesterol lowering, antioxidative, cardio-protective, anti-diabetic and anti-proliferative effects (Alasalvar et al. 2020). Nuts are mostly consumed as whole, raw or toasted; however, nuts protein based value-added products are also available in market.

2.3.1 Almond Protein

Almond is a popular tree nut consumed as a part of healthy diet due to its wide availability and health significance. Almond is also considered as a common culinary ingredient for formulating dairy desserts in many cultures and is used in many forms e.g., whole, gritted, slivered and as nibs for decorating finished goods. Almond protein powder is utilized in value addition of multiple food categories such as ready-to-drink protein shakes/smoothies, breakfast cereals, high-protein nutrition bars and food service products (de Carvalho et al. 2011; Hashemi et al. 2017). Almond protein is preferred over whey, soy, or pea protein and has significantly higher purchase intent due to its nutty flavor and extra-fine smooth texture. Almond meal-based confection "*Marzipan*" is a protein-rich original fondant traditionally has been prepared in the Middle East and Mediterranean regions for making decorative shapes. To develop *Marzipan*, almond meal is cooked with sugar or honey followed by cooling and crystallizing the mixture. In addition, a binding agent such as egg white, gelatin or starch syrup is added to improve binding and moulding properties (Romero et al. 2001; Eby 2020). Use of almond in the formulation of plant-protein based beverages and imitation milks is much popular. Almond milk is naturally cholesterol and lactose free dairy alternative for vegans and individuals suffering with lactose intolerance (Salpietro et al. 2005; Kundu et al. 2018). Commercial almond milk is usually flavored (vanilla or chocolate) and fortified with micronutrients such as calcium and vitamin D. It is reported that global market of almond milk was 5.8 billion US dollar in 2018 and estimated to reach 13 billion US dollar by 2025 (Coppola 2020).

2.3.2 Walnut Protein

Walnut is another member of nut family recognized to contain significant amounts of protein (18–24%), heart friendly polyunsaturated fatty acids (PUFA) and phytonutrients (Sze-Tao and Sathe 2000). Walnut protein concentrates and isolates are added as potential functional food ingredients in multiple food formulations such as fudge, cakes, soups, sauces and salad dressings (Mao and Hua 2012; Barber and Obinna-Echem 2016). In an attempt to develop protein-rich bread, walnut flour was supplemented in wheat flour at different levels (20–50%). Results revealed that walnut flour substitution at 30% gave best overall quality attributes to bread and enhanced ~46% protein content as compared to control (Almoraie 2019). Recently, a walnut protein based-edible coating was prepared by Grosso et al. (2020) and applied on the surface of walnut kernel to increase shelf life. On day 84, kernels covered in walnut protein based-coating preserved walnut flavor, inhibited genesis of oxidized and cardboard flavors, improved γ-tocopherol (306.78 mg/kg) and carotenoid contents (2.01 mg/kg) and prevented PUFA deterioration. Furthermore, walnut protein-based coating was preferred by consumers over methylcellulose coating and could be used as a natural alternative to prolong the shelf life of nuts.

2.3.3 Pistachio Protein

Pistachio is a nutrient dense food cultivated in Mediterranean, central and southwest Asia. They are good source of vegetable protein constituting 20% essential amino acids which exert antiplatelet and antioxidative effects (Terzo et al. 2019). A study by Shakerardekani et al. (2013) reported that pistachio nut could be a good source of plant proteins to develop dairy alternative imitation milk. The best processing conditions to develop pistachio milk include milling of roasted kernels and blending the pistachio slurry at pH 8.5 for 30 min. Moreover, sensorial properties of pistachio milk could be enhanced by the addition of 5.0% sugar and 0.02% vanilla flavor.

2.4 Edible Seeds Protein-Based Products

Inclusion of edible seeds in the diet is a worldwide growing demand of consumers for the consumption of plant-based healthy ingredients (Sá et al. 2020). Flaxseed is amongst richest sources of high-quality protein, soluble fiber and phytonutrients. Apart from lysine, flaxseed proteins deliver good concentration of essential amino acids mandated for human nutrition requirements (Panaite et al. 2017). Giacomino et al. (2013) suggested that extrusion of flaxseed meal increases its nutritional quality without disturbing stability of amino acids. These authors incorporated extruded flaxseed meal in flour mixes and cereal-based bars and recorded significant increase in protein levels (20% and 17%, respectively) with improved protein digestibility and biological value. Similarly, in another study by Hussain et al. (2012) flaxseed flour (raw and defatted) supplementation in unleavened flat breads improved levels of essential amino acids and total dietary fiber.

Pumpkin seed is another rich source of protein (24.5–36.0%) used for the enrichment of multiple products such as cereal bars, breads and cookies (Costa et al. 2018). Quanhong and Caili (2005) proposed various extraction procedures of protein from germinated pumpkin seeds. Pumpkin protein based edible films are reported to have strong mechanical and barrier properties thus have potential to be utilized for packaging purpose (Lalnunthari et al. 2019).

Oil seed crops such as rapeseed and sunflower seeds are considered enriched sources of plant proteins. The extracted fractions of rapeseed and sunflower seed proteins have been incorporated in many baked goods to improve nutritional profile of finished products (González-Pérez and Vereijken 2007; Tan et al. 2011).

Rapeseed (*Brassicaceae* family) a herbaceous annual plant cultivated as oil seed crop contains approximately 17–26% of protein (Li et al. 2012; Lim 2012). The protein isolates of rapeseed contain at least 90% protein and may be considered as good alternatives to other plant proteins resources. On account of availability of a balanced amount of amino acids, rapeseed proteins can also be used in formulating gluten free bakery products, biscuits and sausage like preparations which may serve functional and therapeutic properties to the consumers (Wanasundara et al. 2016; Ostrowska et al. 2018). Sunflower seeds are used for oil purpose but the dehulled sunflower seeds contain higher amount of protein (20–40%) as well. Sunflower protein application has been suggested to fortify variety of edible goods including infants formulas, milk, meat and bakery products (González-Pérez and Vereijken 2007) (Table 2.7).

3 Conclusion

The findings of the recent research advocate plant proteins as cost-effective, nutritionally enriched and environment friendly sources of protein to meet the global protein supply needs. The utilization of plants-derived proteins in novel product formulations might serve as a desirable vehicle to fulfil the dietary demands of globally escalating population. The various food product with variable protein concentrations impart desired qualitative features and attracts the consumers depending on their desired eating preferences and possess specific nutritional, functional and therapeutic properties. Conclusively, it has been declared that food products incorporated with plant protein concentrates are good alternatives in provision of health benefits for the people who are allergic and for those who can't afford the high cost of protein from animal resources. Therefore, these resources have been declared as poor man's meat. Incorporation of protein concentrates in the development of various products may enhance the utility of plant based protein products and would be of human health significance in maintaining their regular essential body requirements.

Table 2.7 Application of nuts and seeds proteins in food products

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Soaked almond	21.15%	1.38%	Almond milk	Almond milk (60%) substitution with soymilk masked beany note and recorded highest sensory scores in terms of overall acceptability.	Kundu et al. (2018)
Almond paste	26–50%	26–50%	*Marzipan* (Confectionary)	An original fondant glazed on multiple sweet products (chocolates and icing cake) for decorative purpose and shaped into small imitations of fruits and vegetables.	Sinclair (2011)
African walnut flour	26.3%	3%	Cookies	The level of likeliness and sensorial attributes of cookies were acceptable at 5–15% walnut flour substitution.	Barber and Obinna-Echem (2016)
Walnut flour	49.36%	2.96%	Edible coating	Walnut kernels covered in walnut protein based coating preserved walnut flavor, inhibited genesis of oxidized and cardboard flavors, improved nutritional profile and prevented PUFA deterioration.	Grosso et al. (2020)
Brazil nut	14%	3.31%	Symbiotic drink	Brazil nut drink proved to be viable dairy alternative with outstanding nutritional quality.	Cunha Júnior et al. (2021)
Roasted pistachio nuts paste	3–4%	3–4%	Pistachio milk	Sensorial properties of pistachio milk were liked by panelist in terms of overall acceptability.	Shakerardekani et al. (2013)

(continued)

Table 2.7 (continued)

Raw material		Percentage added in the food preparation	Product/ enriched product	Remarks	Reference
Protein Source	Protein Content				
Flaxseed meal	26.35%	7.12%	Cereal-based products	Extruded flaxseed meal incorporation in flour mixes and cereal-based bars significantly increased protein contents and improved protein digestibility.	Giacomino et al. (2013)
Fluted pumpkin seed flour	28.88%	2.8–14.4%	Bread	Fluted pumpkin flour showed acceptability at 20% substitution level in wheat flour for bread making and gave desired loaf volume quality.	Agu et al. (2010)
Watermelon seed protein concentrates	72.26%	2.5–10%	Cookies	Watermelon seed protein addition increased dough stability, mixing tolerance index and cookies spread facto at 5–7.5% substitution level and produced cookies with improved protein quality.	Wani et al. (2015)

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