PROTERRA®

PLANT-BASED TEXTURED PROTEINS

TECHNICAL SPECIFICATIONS

All of our proteins, excluding malt - and caramel-colored ProTerra, are Non-GMO Project Verified.

MGP®

Create Exceptional™

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PROTERRA® PLANT-BASED TEXTURED PROTEINS ▸ Introduction

Protein as part of a well-balanced diet is a major source of nutrition for the general population. The recommended Daily Reference Intake is 0.8 grams of protein per kilogram of body weight or 0.36 grams of protein per pound of body weight. For the purpose of labeling, the U.S. Food and Drug Administration (FDA) recommends that the Daily Reference Value for adults and children four or more years of age shall be 50 grams of protein. The right amount of protein for any one individual depends on age, gender, muscle mass, level of activity and current state of health. Dietary guidelines state that 10% to 35% of calories in a healthy diet should come from protein.

The current U.S. nutrition guide, MyPlate, recommends consumption of protein-rich foods from meat, poultry, seafood, beans/peas, eggs, processed soy products, nuts and seeds. Vegetarian/vegan options in the protein-rich group are somewhat limited, which allows for serious consideration of high protein processed products from other grains and pulses. While some protein-rich meat substitutes like tofu and seitan have been around for many years, the popularity of other meat substitutes derived from wheat, pea, black beans, ancient grains, potato, jackfruit and mushrooms among others have increased recently. The technology of cellular agriculture (i.e. laboratory-grown meat from animal cells) is also being investigated by several companies. Healthful eating and sustainability are the major drivers in consumers' desire for non-animal sources of food in the diet.

The current world population of 7.6 billion is projected to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100 according to the United Nations. As the world's population grows, the need to produce an ample supply of protein-rich foods that are healthy and environmentally-friendly becomes a high priority. It is a common belief that the environmental burden of vegetarian foods is relatively low compared to animal meat. For example, in comparing soy protein and meat protein, a variety of environmental considerations (e.g. land use, water requirements and fossil fuel requirements) associated with production and processing of these proteins are a factor of 4.4 to >100 to the disadvantage of meat. One study in the UK showed that a reduction in meat consumption would lead to a reduction in dietary greenhouse gas emissions.

Vegan foods that appeal to vegans, vegetarians, and omnivores alike are gaining popularity to make the world less dependent on animal-based foods. Value-added ingredients derived from wheat protein were developed to extend its benefits to food applications where wheat protein has not been traditionally used, such as extended processed meat products and vegetarian/vegan foods. An example is textured wheat protein. Its properties, functional qualities and food applications are highlighted in this booklet.

PLANT-BASED PROTEINS

Plants constitute a primary source of carbohydrates, proteins, fats/essential fatty acids, vitamins, minerals, and utilizable energy for the production of human foods. Farmers have cultivated about 150 plant species for commercial production, but the world's population depends primarily on 20 different crops consisting of a number of cereals (grains), vegetables (including legumes/pulses), fruits and nuts. Currently, the common sources of plant-based proteins come from cereals (wheat, corn, rice, oat, rye, barley), legumes (soybean, pea, lentil, chickpea, beans, lupin), oilseeds (canola, flaxseed, sunflower, hemp), ancient grains (quinoa, chia, teff, millet, sorghum) and other sources (potato, algae, fungi (mushroom), yeast, nuts and leaves).

Plants and animals provide the world's supply of edible proteins, with developed countries consuming elevated amounts per capita compared to economically-depressed or under-developed countries. For sustainability reasons, the nutritional aspects of plant foods, especially the adequacy of proteins in the diet, are receiving increased attention.

The protein ingredient segment represents a multi-billion dollar industry dominated by animal (whey, casein, egg white, and gelatin) and plant (soy and wheat) proteins. Due to rising costs of animal-based proteins and increasing demand for new ingredients in food and beverages, along with sustainability concerns, trends have shifted toward more plant-based proteins. In addition, plant-based proteins resonate well with consumers looking for non-GMO, allergen-free and healthful ingredients. Protein's health halo continues to persist due to claims that it can help build lean muscle, induce satiety, slow the effects of sarcopenia (i.e. the loss of muscle mass, strength, and function related to aging) and even help with weight loss.

The plant-based protein trend is particularly evident in meat and dairy product categories as consumers look for suitable alternatives that offer the benefits they desire. Food products like yogurt, milk, frozen desserts, cheese and burgers made from grains, nuts and pulses are now visible in the aisles of most grocery stores and supermarkets. In a 2015 R&D Protein Trends Survey (Global Food Forums), functionality (67%) is the top attribute in formulating proteins, followed by price (49%), nutritional quality (46%), allergenicity (42%), consumer popularity (34%), reliability of supply (30%), familiarity with how to use it (15%), and ease of substitution with alternatives (7%).

An annual food and health survey conducted in 2017 by the International Food Information Council Foundation showed that 73% of shoppers view plant proteins as healthy compared with only 38% for animal proteins. Driven by health, environmental and animal welfare concerns, more than a third of Americans buy plant-based meat alternatives and about a quarter of consumers eat less animal meat. Raising livestock requires a lot of water, land and feed from plant sources. Other concerns include food allergies, hormones and antibiotic usage. Vegetarians and vegans account for about 9% to 15% of U.S. consumers while others identify themselves as "flexitarian" or "lessitarian" indicating that they reduced their consumption of animal-based products. To reduce meat consumption, many Americans are also embracing popular trends like "meatless Mondays."

U.S. retail sales of plant-based meat analogs in 2017 generated $565 million in revenue at an annual growth rate of 7.6% (Nielsen data). Global sales of plant-based meat alternatives are estimated to reach $5 billion in 2020, according to Plant-Based Foods Association, and will grow to $5.81 billion by 2022 at a compound annual growth rate of 7.7%. According to Mintel, taste (52%) is the top reason U.S. consumers choose to eat plant-based proteins followed by health (39%), the environment (13%), animal protection (11%), and diet (10%).

WHEAT GLUTEN PROTEINS

The wheat gluten proteins correspond to the major storage proteins that exist as a continuous matrix surrounding the starch granules in the endosperm of mature wheat grain. Hard wheats contain 10-14% protein while soft wheats contain 8-11% protein and durum wheats have protein levels ranging from 9-18%. In general, wheat contains 15-20% non-gluten-forming proteins consisting of water-extractable albumins and globulins that are extractable in salt solutions but not in water. The remaining 75-80% are gluten-forming proteins that are comprised of gliadins (extractable in aqueous ethanol) and glutenins (unextractable in aqueous ethanol). Together, gliadins and glutenins comprise wheat gluten.

Wheat gluten is the cohesive and viscoelastic protein mass separated as a co-product during the isolation of starch from wheat flour by a wet-processing method. Commercially, it is sold in the food industry as a dry powder, called "vital wheat gluten," to increase the protein content of low protein wheat flours, add strength to marginal quality flours, or for use as an ingredient for many food and non-food uses. Wheat is unique because of the viscoelastic properties (Fig. 1) of wheat gluten (which is not duplicated by other food proteins) that is capable of forming a continuous dispersed network (i.e. dough), retaining gas bubbles, giving volume to bread, and providing a soft spongy texture with elastic tear. Gluten absorbs about 1.5 to 2 times its dry weight of water to form a cohesive, viscoelastic matrix. Highly elastic doughs are required for bread making whereas extensible doughs are essential for making cakes and cookies.

Figure 1. Appearance of hydrated wheat gluten demonstrating its viscoelastic and film-forming properties.

The typical average composition of commercial vital wheat gluten is 72.5% protein (77.5% on dry basis), 5.7% total fat, around 15% carbohydrates (mainly starch together with some dietary fiber and sugars), 0.7% ash, and 6.4% moisture. Its nutritional composition is shown in Table 1 and its amino acid composition is presented in Appendix A.

The protein that makes up wheat gluten is a complex mixture of proteins, about half being monomeric gliadins and the other half being polymeric glutenins. The molecular weight distribution of wheat gluten showing polymeric and monomeric proteins determined by size exclusion chromatography is shown in Appendix B. Hydrated gliadins exhibit extensibility and plasticity, whereas hydrated glutenin demonstrates strong elastic properties.

Gliadins consist of single chain polypeptides capable of forming intra-molecular disulfide bonds and having molecular weights of up to 70,000 daltons. The gliadin proteins consist of structurally different groups called α-, β-, γ- and ω-gliadins based on their mobilities when separated by electrophoresis at low pH. Due to close similarities in sequence and structure, α- and β-gliadins are usually referred to as α-type gliadins. The α- and β-gliadins have very similar primary structure consisting of three different regions: a short non-repetitive N-terminal domain; a central domain lacking cysteine, formed by repetition of two proline- and glutamine-rich sequences; and a long C-terminal domain containing six cysteine residues and most of the charged amino acids. The γ-gliadins also consist of three different regions: a short N-terminal domain; a repetitive central domain formed by repeated proline- and glutamine-rich sequences; and a C-terminal domain containing eight cysteine residues and most of the charged amino acid residues.

The six and eight cysteine residues in α-gliadins and γ-gliadins, respectively, are involved in intra-chain disulfide bonds. By contrast, ω-gliadins lack cysteine residues. The ω-gliadins have a peculiar sequence because they lack cysteine and consist of a single repetitive domain in which 80% of the residues are glutamine, glutamate, proline, and phenylalanine.

The α-gliadins adopt a compact and less regular structure while the γ-gliadins form an extended-spiral tertiary structure. The ω-gliadins form a stiff coil rather than a compact structure. The ω-gliadins have molecular weights ranging from 46,000 daltons to 74,000 daltons, whereas the molecular weights of the other gliadins range from 30,000 daltons to 45,000 daltons.

The glutenins are multiple chain polymers in which the individual polypeptides or subunits are linked by inter-molecular disulfide bonds. After reducing the inter-chain disulfide bonds, the glutenin proteins can be separated into high-molecular weight subunits (20%) and low-molecular weight subunits (80%) by electrophoresis in the presence of sodium dodecyl sulfate. The high-molecular weight glutenin subunits have an apparent molecular weight of 80,000-160,000 daltons and low-molecular weight glutenin subunits have an apparent molecular weight of 30,000-55,000 daltons. Because of the polymerizing ability through disulfide bonding, the molecular weight of glutenin can vary widely from 100,000 to several million daltons. These disulfide bonds play a significant role in determining gluten elasticity through the formation of large glutenin aggregates.

The low-molecular weight glutenin subunits can be classified further according to composition, size and isoelectric points into B-, C-, and D-type subunits. The B-type is comprised of components which form a discrete group of sulfur-rich prolamins while the D-type appears to be related to ω-gliadins. The C-type is related to α- and γ-type gliadins. The primary and secondary structures of low-molecular weight glutenin subunits are similar to those of α- and γ-gliadins, but differ in that low-molecular weight glutenin subunits contain intra-chain disulfide bonds and also inter-chain disulfide bonds that facilitate incorporation into glutenin polymer.

The high-molecular weight glutenin subunits form a distinct group called the high-molecular weight prolamins, which are not closely related to any of the gluten proteins. They are classified into two types; a higher molecular weight (83,000-88,000 daltons) x-type and a lower molecular weight (67,000-74,000 daltons) y-type. The high-molecular weight glutenin subunits consist of three structural domains comprised of a non-repetitive N-terminal domain (80-105 residues), a repetitive central domain, and a C-terminal domain of 42 amino acid residues. The N- and C-terminal domains contain frequently-occurring charged amino acid residues and cysteine. The central domain contains a backbone of repetitive hexapeptides (glutamine-glutamine-proline-glycine-glutamine-glycine) with inserted tripeptides (e.g. glutamine-glutamine-proline or glutamine-proline-glycine) and hexapeptides (e.g. tyrosine-tyrosine-proline-threonine-serine-proline). The central domain promotes intermolecular hydrogen bonding whereas the N- and C-terminal domains form inter- and intra-chain disulfide bonds. In high-molecular weight glutenin subunits, the x-type subunits contain four cysteine residues: three in the N-terminal and one in the C-terminal domain. The y-type subunit has seven cysteine residues: five in the N-terminal domain, one within the repetitive central domain, and one close to the C-terminus. The direct correlation between high-molecular weight glutenin subunits composition and grain processing quality (e.g. gluten strength or loaf volume potential) is well understood among researchers.

This unique protein composition of wheat gluten confers distinct structural and functional properties that make possible its diverse applications in many food and non-food products. The uses of gluten vary worldwide and consist of flour fortification and applications in bakery products, breakfast cereals, pasta, noodles, meat products, vegetarian/vegan foods, pet foods and pet treats/chews. The largest volume is consumed in the bakery and pet food industries. Wheat gluten is acceptable for use as a binder (2% max.) for fresh meat cuts (e.g. boneless loins, boneless legs and liver) and home-style meatloaves. Seitan or gluten meat is made from hydrated wheat gluten and is used particularly to replace meat. The product receiving major attention today is textured wheat protein for the manufacture of vegetarian/vegan foods and for partial replacement of meat in a number of processed meat products.

Table 1. Nutritional composition of vital wheat gluten.

Nutrient	Amount per 100 grams
Water, grams	*7.02*
Calories, by calculation	*392.60*
Protein (N x 5.7), grams	*74.38*
Total Fat by GC, grams	*5.02*
Saturated Fat, grams	*1.07*
Monounsaturated Fat, grams	*0.80*
Cis-Cis Polyunsaturated Fat, grams	*2.91*
Trans Fat, grams	*<0.10*
Carbohydrates, by calculation, grams	*12.50*
Total Dietary Fiber, grams	*1.81*
Ash, grams	*1.08*
Calcium, milligrams	*50.00*
Iron, milligrams	*4.00*
Sodium, milligrams	*85.40*
Potassium, milligrams	*88.70*
Cholesterol, milligrams	*<0.10*
Total Sugars, grams	*0.98*
Fructose, grams	*<0.25*
Glucose, grams	*<0.25*
Sucrose, grams	*<0.25*
Maltose, grams	*0.98*
Lactose, grams	*<0.25*
Vitamin D2, micrograms	*<0.75*
Vitamin D3, micrograms	*<0.55*
Total Vitamin D, micrograms	*<0.55*

METHODS OF TEXTURIZING PROTEINS

Texturization takes place when discrete particles of protein acquire a substantially continuous phase that resembles the appearance and texture of meat. Plant-based proteins have demonstrated to be capable of being texturized into structured bodies having fiber-like appearance. The texturized protein product once rehydrated has found widespread use as an extender of fresh and processed meat products and as the meat-like ingredient in many ready-to-eat or easy-to-prepare processed food items. Texturization of proteins can be achieved by several methods such as spinning, steam injection, jet-cooking, extrusion or shear-cell technology.

The classical spinning process consists of pumping an alkaline solution of a protein isolate through a spinneret (a die containing many hundreds of pin holes measuring from 50-250 micrometers in diameter) into a coagulation bath containing acid and salt to form insoluble protein fibers. The acid can be acetic, phosphoric or lactic acid at various concentrations and the salt most often used is 2-20% sodium chloride. The coagulated fiber bundles are then recovered, neutralized, washed, spin-dried and then immersed in binding agents. On a molecular level, it is hypothesized that the native globular structure of a protein isolate is unfolded and denatured in the alkaline medium. Molecular orientation results from the shearing flow in the spinneret. Then, protein molecules become oriented by streaming in the elongational flow. Microscopic observation reveals the structure of spun proteins to be analogous to meat or fish muscle fibers. However, others observed that the spun product appears flake-like or spongy.

A special texturizing apparatus for steam texturization of proteins was described in the 1970s. A dry blended mixture of a protein material together with other ingredients was hydrated to about 20% moisture. The moistened mixture was then fed to the tank of the texturizing apparatus at a rate of 10 lbs per minute. Steam was injected at a temperature range of 430-450°F and a pressure ranging from 120-180 psig. The pressure in the tank was maintained at around 70-100 psig. The material exiting the nozzle was well textured and had a moisture content of about 17.5%. The texturized material was found to be a good meat extender. By using an improved version of the texturizing apparatus, water was added to the protein material to raise the moisture content to 80%. The slurry was then pumped to the texturizing apparatus under a pressure of 170 psig. The slurry was sprayed into the steam stream using an atomizing nozzle. The steam pressure was 95 psig and the temperature was 485°F. This treatment texturized the protein to a meat-like product, which had a moisture content of 8%. Steam texturized proteins have the appearance of cooked ground beef. Thus, further improvements on this technology were developed to yield a layered or striated muscle-like structure in the finished product.

Another method for texturizing proteins consists of jet cooking a protein slurry. Typically, a protein slurry (25% solids) is pumped at a pressure of 5,000 psig through a stainless steel heat exchanger where the temperature is set at 300°F. The retention time of the slurry in the heat exchanger is about 5 minutes. The slurry is then expelled through a 0.0135-inch diameter circular nozzle and cooled by dropping 20 feet through ambient air into a collecting vessel. The fibers are recovered and excess water is removed by centrifugation. The resulting product has a fibrous structure that simulates the chewiness of meat fibers.

Press texturization uses a heated press for texturing plant-based proteins. A press is heated to a temperature of 150°C and the plant protein at 40% moisture is heated at pressures of 25 atm for 5 sec. The press is then suddenly opened causing the material to expand quickly, flashing off some moisture, and yielding a texturized expanded patty. Press texturization is applicable to plant proteins with high fat content.

In general, extrusion refers to processes whereby starchy or proteinaceous materials are passed through a jacketed auger under conditions of high pressures, temperatures, and mechanical shear to alter the appearance and texture of the material. Extrusion technology plays a dominant role in the food industry, especially in the snack, breakfast cereal, pasta and textured protein markets. The extrusion process generally involves high temperature (120-170°C) and short-time processing, with most of the energy coming from friction and the heated barrel. Single-screw extruders were first used in the 1940s whereas twin-screw extruders were developed in the early 1980s. Although single-screw extruders were quite popular in the food industry, twin-screw extruders, which contain two rotating screws inside the barrel, are preferred for protein texturization because of their versatility in handling different ingredients and formulations and in the production of final products with desired shapes and textures. With proteins, extrusion creates filamentous, striated or porous structures by restructuring folded, globular structures into a stretched, layered or cross-linked network.

An innovative shear cell technology has been developed recently providing a new generation of meat substitute, steak-like products from plant-based proteins. The Couette Cell, a machine developed in Wageningen University and Research (The Netherlands), uses shear cell technology, which is based on the principles of a rheometer using well-defined flow field for structuring biopolymer materials. In the shear cell, these shear forces are applied to the materials by a rotating plate and a stationary cone. Process parameters may involve temperatures ranging from 90-110°C, rotation rates of 5-50 rpm and processing times of 5-25 min. Plant-based protein sources that have been examined are soy, wheat, pea, rapeseed and corn among others. The finished steak-like products have layered, fibrous structures, texture, mouthfeel and overall eating experience resembling that of real meat. Compared to other technologies, the shear cell technology has lower cost of investment and energy input, but greater flexibility in production.

TEXTURIZATION OF PROTEINS BY EXTRUSION

Texturization of protein results in the development of a physical structure that, when eaten, will provide a sensation of eating meat. Meat analogs or extenders were first produced using extrusion technology in the 1960s. They represent the largest portion of textured plant proteins, which upon hydration can be used wholly with other ingredients to make meatless food products, or blended with meat or meat emulsions to make extended meat products. Meat extenders from textured plant proteins have the advantage of retaining meat juices and fat and reducing cooking loss.

For the School Lunch Program, the U.S. Department of Agriculture (USDA) in 1971 defined "textured vegetable protein products" as food products made from edible protein sources and characterized by having a structural integrity and identifiable structure such that each unit will withstand hydration and cooking, and other procedures used in preparing the food for consumption. By comparison in 2011, the term "textured protein products" was defined as fabricated palatable ingredients processed from an edible protein source, including among others soy grits, soy protein isolates, and soy protein concentrates with or without suitable ingredients added for nutritional or technological purposes.

Extrusion is a process in which moistened starchy and/or proteinaceous materials are plasticized in a tube by a combination of moisture, pressure, heat and mechanical shear. During the extrusion process, thermal and mechanical energy are applied, resulting in starch gelatinization and the unraveling of protein's native, organized (globular) structure with consequent formation of a continuous plastic-like mass (i.e. protein

TEXTURIZATION OF PROTEINS BY EXTRUSION ▸ Continued

lava) inside the barrel. Proteins unfold and undergo denaturation during the moist thermal and shearing conditions of extrusion. Disulfide bonds are broken, but may subsequently re-form. Protein-protein interactions like electrostatic and hydrophobic bonding occur. Contemporaneous protein cross-linking and other interactions, plus the alignment of the protein lava in the direction of the flow, creates the laminar and meat-like fibrous appearance generally observed in most textured plant proteins. With proper choice of the die and post-extrusion processing equipment, the finished product may appear as chunks, flakes, bits, granules, shreds, slices, fibers or other forms. In addition to yielding a fibrous, meat-like product, the extrusion process results in the reduction of protein solubility, an increase in digestibility, deactivation of temperature-sensitive enzymes and inhibitors, reduction of bitter flavors, homogeneous bonding of ingredients, and a reduction of microbial load. The final product has low moisture and water activity, which facilitates handling and storage with extended shelf-life.

Textured protein products traditionally used soy protein as the primary protein source, but other plant-based protein sources such as wheat gluten, pea protein concentrates and isolates, defatted peanut flour, de-glanded cottonseed flour, canola (rapeseed) protein concentrate, sesame, sunflower, lentil, chickpea, green pea and yellow pea are showing increasing use. There are different types of textured plant protein products available in the market, namely: chunk-style textured protein, structured meat analog, fibrous textured protein, high-moisture meat analog, low-moisture meat analog, textured meat protein (using plant protein and meat together), and high-protein snacks. These textured protein products can be added to meat as extenders or can be consumed directly as simulated meat analogs. Challenges for product developers working with plant-based protein sources for texturization are the protein's commercial availability, flavor, digestibility, nutritional quality, functionality, allergenicity, and gluten-free and GMO status.

Many factors or variables are adjusted in the extruder barrel, screw, die, and feed, which influence the viscosity of the material inside the barrel, the residence time and the amount of shear applied. The formation of a fibrous structure is favored when extrusion is conducted at a pH near the isoelectric point of the protein. Variations in feed composition, extruder make-up, and extrusion conditions are known to impact the final end-product quality.

TEXTURED WHEAT PROTEIN

Textured wheat protein was successfully developed using extrusion technology for use in formulating vegetarian/vegan (meatless) foods, as well as extending processed meat products. It is available commercially under the brand name ProTerra® and is sold in several forms differing in size, shape, color, texture, hydration rate, hydration capacity and bulk density (see Appendix F for ProTerra® Sample Guide). Shapes can vary from granules to chips/flakes or shreds of different sizes. When textured wheat protein is prepared for consumption by hydration, cooking, retorting or other heating procedures, they retain their structural integrity and characteristic chewy texture. Analysis of the different ProTerra® ingredients showed that they are high in protein, but low in fat (Table 2).

The amino acid composition of a ProTerra® ingredient (ProTerra® 1200) is presented in Appendix C.

In its natural (uncolored), optimally hydrated form, ProTerra® exhibits a resilient fibrous texture mimicking chicken meat while the malt- or caramel-colored product resembles pork or beef meat (Fig. 2). Depending on the size and shape of the ProTerra® product, bulk density can vary from 10 to 20 lbs/cu. ft.

Hydration rate and hydration capacity measured with ambient temperature water (70-72°F or 21-22°C) can vary from 10 to 120 min. and from 1.3 to 3.7 g water per g ProTerra®, respectively (Table 3). The typical shapes of hydration curves for ProTerra® 1200, ProTerra® 1100 and ProTerra® 1350 are demonstrated in Figs. 3-5 (see Appendix D for hydration curves of all ProTerra® ingredients). If a warmer water is used, it is expected that the hydration rate will decrease while hydration capacity will increase.

Table 2. Protein, fat, dietary fiber, and calorie content of different ProTerra® ingredients.

Product	Protein (N x 6.25), % as is	Total Fat % as is	Total Dietary Fiber % as is	Calories no fiber correction
ProTerra® 1150M	77	5.4	1.4	394
ProTerra® 1300	69	4.7	<1.0	384
ProTerra® 1300C	64	3.7	<0.1	372
ProTerra® 1350	64	4.4	<0.1	372
ProTerra® 1350C	64	3.7	<0.1	372
ProTerra® 1350DC	60	4.2	<0.1	377
ProTerra® 1100	65	4.6	2.3	371
ProTerra® 1100C	65	5.0	2.3	383
ProTerra® 1200	61	4.3	0.8	372
ProTerra® 1200C	59	4.2	1.3	378
ProTerra® 1200DC	60	3.3	1.7	374

Moisture = 10% max.

TEXTURED WHEAT PROTEIN ▶ Continued

Figure 2. Hydrated ProTerra® 1350, ProTerra® 1350C, and ProTerra® 1350DC showing a fibrous structure resembling the fleshy appearance of chicken meat, pork meat and beef meat, respectively.

ProTerra® 1350

ProTerra® 1350C

ProTerra® 1350DC

Table 3. Hydration capacity and hydration times of different ProTerra® products (water temperature = 21-22C°).

Product	Hydration Capacity, g water/g ProTerra®	Hydration Time, min.
ProTerra® 1150M	1.3-1.4	60-120
ProTerra® 1100	2.8-3.0	10-20
ProTerra® 1100C	2.8-3.0	20-30
ProTerra® 1300	2.4-2.5	40-60
ProTerra® 1300C	2.4-2.6	40-60
ProTerra® 1350	2.5-2.6	40-60
ProTerra® 1350C	2.5-2.7	40-60
ProTerra® 1350DC	2.3-2.4	40-60
ProTerra® 1200	3.3-3.4	10-20
ProTerra® 1200C	3.3-3.7	10-20
ProTerra® 1200DC	2.7-2.9	10-20

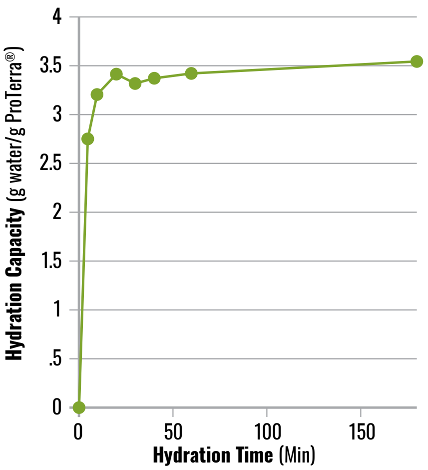

Figure 3. Hydration curve of ProTerra® 1200 (water temperature = 70-72°F or 21-22°C)

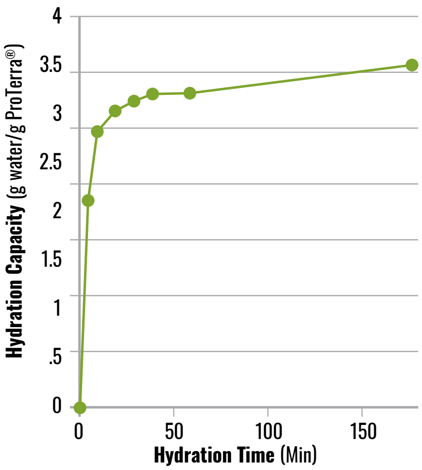

Figure 4. Hydration curve of ProTerra® 1100 (water temperature = 70-72°F or 21-22°C)

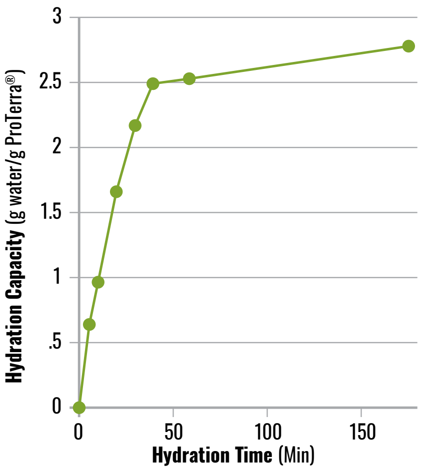

Figure 5. Hydration curve of ProTerra® 1350 (water temperature = 70-72°F or 21-22°C)

To simulate retort conditions, optimally hydrated ProTerra® ingredients were heated to 250°F or 121°C (20 psi) for 10 min. The ProTerra® products endure this high-temperature treatment and maintain piece and fiber integrity (Figs. 6-8 and Appendix E).

Figure 6. Appearance of ProTerra® 1100 in dry state, after hydration, and after hydration then heating to 250°F or 121°C (20 psi) for 10 min.

Dry (before hydration)	Hydrated	Hydrated then heated to 250°F or 121°C (20 psi) for 10 min

Figure 7. Appearance of ProTerra® 1350C in dry state, after hydration, and after hydration then heating to 250°F or 121°C (20 psi) for 10 min.

Dry (before hydration)	Hydrated	Hydrated then heated to 250°F or 121°C (20 psi) for 10 min

Figure 8. Appearance of ProTerra® 1200DC in dry state, after hydration, and after hydration then heating to 250°F or 121°C (20 psi) for 10 min.

Dry (before hydration)	Hydrated	Hydrated then heated to 250°F or 121°C (20 psi) for 10 min

TEXTURED WHEAT PROTEIN ▶ Continued

The fibrous structure remained intact and resilient even after heat treatment as demonstrated by three ProTerra® products (Fig. 9).

Figure 9. Appearance of the fibrous structure of ProTerra® 1350, ProTerra® 1350C and ProTerra® 1350DC after hydration then heating to 250°F or 121°C (20 psi) for 10 min.

ProTerra® 1350 ProTerra® 1350C ProTerra® 1350DC

There are numerous benefits of using the ProTerra® ingredients in food applications, namely: resilient fibrous structure, chewy texture, clean neutral flavor, low fat content, ease of storage and adaptable size, shape, and color. Furthermore, the absence of certain components such as cholesterol, hormones, antibiotics and estrogen-mimicking compounds makes ProTerra® a desirable ingredient of choice for many product developers. Examples of meatless food products formulated with ProTerra® ingredients are shown in Table 4. Extended meat products with added ProTerra® ingredients are shown in Table 5.

Table 4. Examples of meatless food products formulated with ProTerra® ingredients and their typical usage levels.

Meatless Food Product	Ingredient	Usage Level, %
Baked Ravioli	ProTerra® 1100C	7.2
Beef Chimichanga	ProTerra® 1350DC/ ProTerra® 1200DC	10.0
Beef Jerky	ProTerra® 1200C	14.0
Beef Taquitos	ProTerra® 1350DC/ ProTerra® 1200DC	22.3
Chicken Enchilada	ProTerra® 1200	10.9
Chicken Nuggets	ProTerra® 1350/ ProTerra® 1200	29.5
Chicken Patty	ProTerra® 1200/ ProTerra® 1100	26.0
Chicken Pizza	ProTerra® 1200	10.3
Chicken Taco Meat	ProTerra® 1200	26.3
Chicken Tortilla Trumpet	ProTerra® 1200	13.4
Cod Fish	ProTerra® 1200	19.7
Croquette	ProTerra® 1200/ProTerra® 1350	13.0/7.7
Hamburger Patty	ProTerra® 1100	30.0
Italian Sausage	ProTerra® 1100C	29.2
Meatballs	ProTerra® 1200DC	27.9
Pepperoni	ProTerra® 1200DC	20.5
Pork Barbecue	ProTerra® 1350C/ ProTerra® 1200C	13.2
Sausage	ProTerra® 1100C/ ProTerra® 1150	18.0/9.7
Shredded Beef Barbecue	ProTerra® 1200DC	7.2

Table 5. Examples of extended food products formulated with ProTerra® ingredients and their typical usage levels.

Extended Meat Products	Ingredients	Usage Level[a], %
Beef Taquito	ProTerra® 1350DC	20.8
Shredded Beef Barbecue	ProTerra® 1200DC	13.2
Shredded Pork Barbecue	ProTerra® 1200C	13.2
Chicken Salad	ProTerra® 1200	28.0
Tuna Salad	ProTerra® 1200	28.0
Meatball	ProTerra® 1350C	15.0
Chicken Nugget	ProTerra® 1300	30.0
Sausage	ProTerra® 1350C	15.0
Sausage Topping	ProTerra® 1350C	30.2

[a]Hydrated ProTerra®

CONSUMER PREFERENCE ▶ Vegetarian Meatballs

Eighty-three Benedictine College (Atichison, KS) students (81% between the ages of 18 and 21) were recruited for a consumer preference study comparing beef-flavored vegetarian meatballs made with textured soy concentrate to meatballs made with a 50/50 blend of textured wheat protein and textured soy concentrate. The volunteers' eating preference characteristics varied and consisted of 20% who consumed non-meat meals every day, 37% who ate a non-meat meal 1-4 times per month, and 30% who ate a non-meat meal 5-10 times per month. Sixty-six percent of the volunteers preferred the beef-flavored vegetarian meatballs made with the 50/50 blend over that of textured soy concentrate (Fig. 10). Both frequent and infrequent consumers of non-meat meals demonstrated equal distribution of preference.

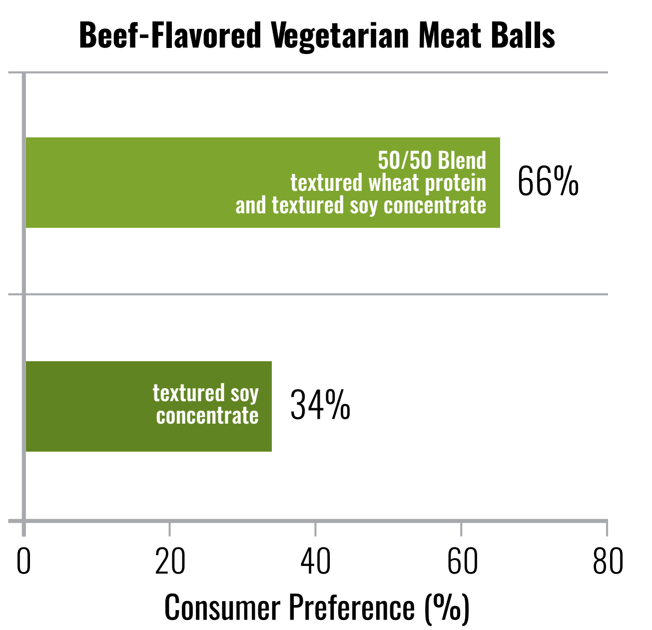

Figure 10. Results illustrating consumer preference for beef-flavored vegetarian meat balls made with 50/50 blend of textured wheat protein/ textured soy concentrate (preference score = 66%) or textured soy concentrate (preference score = 34%).

SENSORY CHARACTERISTICS ▸ Extended Chicken Nuggets

In an extended chicken nugget application, 10%, 15%, 20%, 25% or 30% of hydrated textured wheat protein or textured soy flour were used to replace comminuted chicken meat to evaluate the physical and sensory properties of deep-fried chicken nuggets (Singapore Polytechnic). The moisture content of cooked chicken nuggets increased gradually with increased usage levels of textured proteins (Fig. 11). Chicken nuggets with 30% textured wheat protein achieved the highest moisture content. Textured wheat protein at 20% and 30% levels reduced cooking loss the most, which is due to the high water retention ability at these levels during the frying process. Nuggets with high moisture content and low cooking loss possess enhanced juiciness.

Chicken nuggets formulated with textured wheat protein exhibited a firmer texture compared to those with textured soy flour as evidenced by a higher force to cut it using a TA-XT Plus Texture Analyzer (Fig. 12). As the level of textured wheat protein rises, the cutting strength increases, with the highest cutting strength demonstrated by nuggets containing 25-30% textured wheat protein.

Using five panelists, a preliminary evaluation was conducted on the sensory characteristics (firmness, springiness, juiciness and aroma) of chicken nuggets formulated with 20% and 30% textured wheat protein or textured soy flour. The results showed that nuggets with 30% textured wheat protein gave the best sensory scores followed by 20% textured wheat protein. Nuggets with textured soy flour were not well received by the panelists due to a beany aftertaste.

A formal sensory evaluation involving 20 panelists was then conducted to evaluate taste, texture, mouthfeel and aftertaste of the nuggets. The panelists ranked the nuggets from the most to least preferred. The nuggets with 30% textured wheat protein was ranked the best followed by the nuggets with 20% textured wheat protein and then the control nugget (Fig. 13). Nuggets with 30% and 20% textured soy flour were least preferred by the panelists.

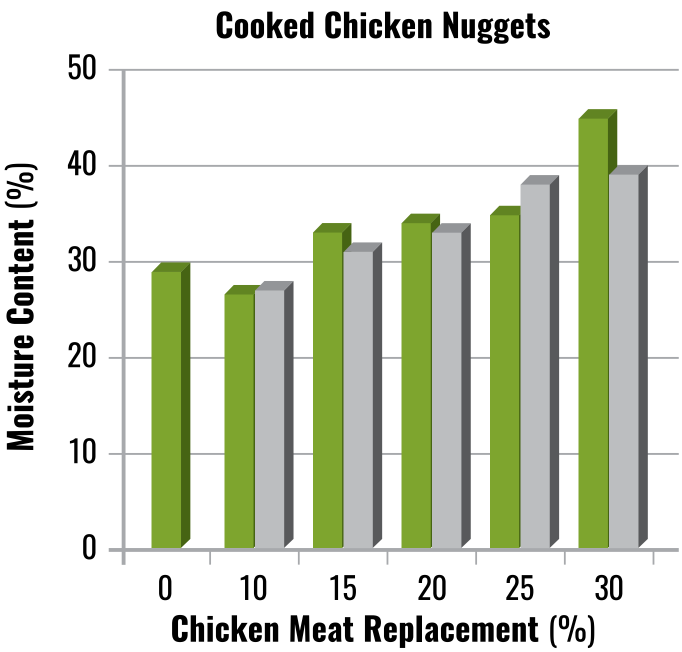

Figure 11. Moisture content of cooked chicken nuggets containing 10-30% of textured wheat protein (green bar) or textured soy flour (gray bar). The control chicken nugget (green bar, far left) is designated as 0%.

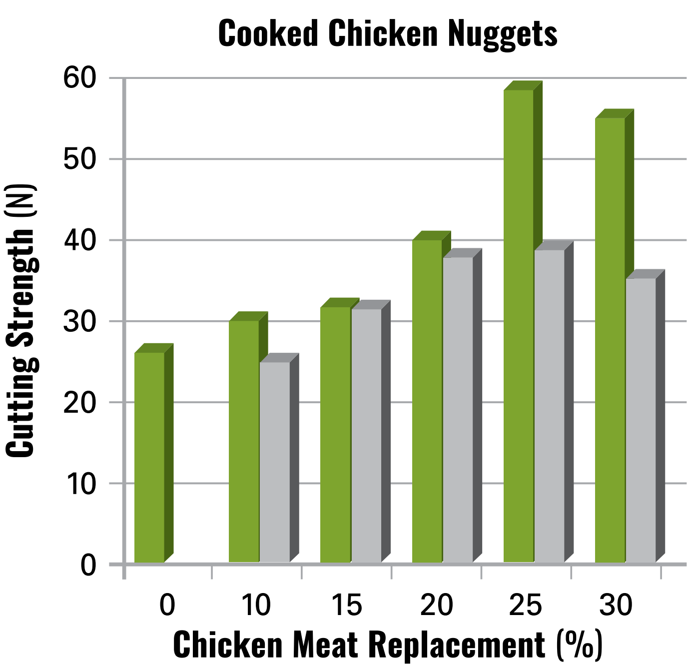

Figure 12. Cutting strength of cooked chicken nuggets containing 10-30% of textured wheat protein (green bars) or textured soy flour (gray bars). The control chicken nugget (green bar, far left) is designated as 0%.

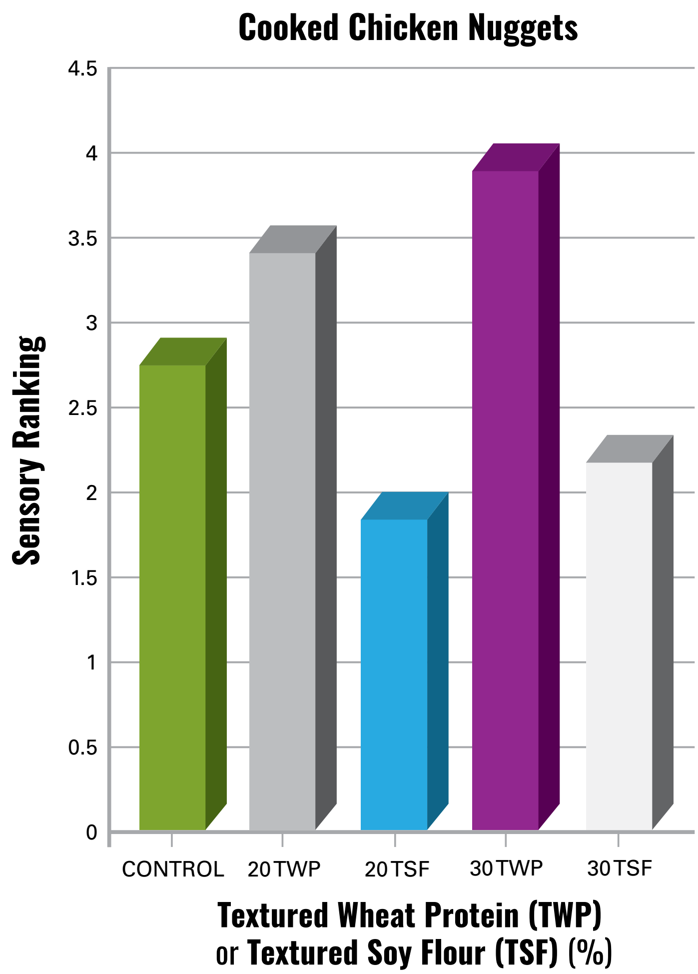

Figure 13. Sensory ranking of cooked chicken nuggets containing 20% or 30% textured wheat protein or textured soy flour. Green bar = control; Gray bar = 20% textured wheat protein; Blue bar = 20% textured soy flour; Purple bar = 30% textured wheat protein; White bar = 30% textured soy flour.

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APPENDIX A

Average amino acid composition[a] of three wheat gluten samples determined by high-performance anion-exchange chromatography with integrated pulse amperometric detection.

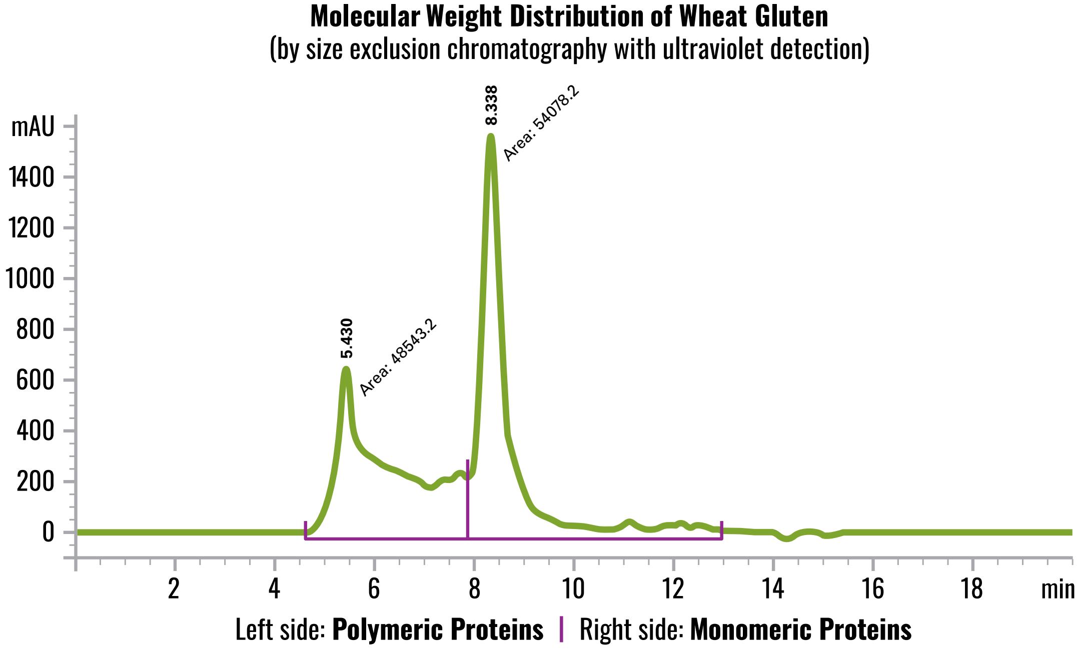
Amino Acid	Mole %
Alanine	3.6
Arginine	3.2
Aspartic Acid	2.9
Cysteine	2.2
Glutamic Acid	31.8
Glycine	5.4
Histidine	1.7
Isoleucine	4.1
Leucine	7.2
Lysine	1.4
Methionine	1.3
Phenylalanine	4.4
Proline	14.0
Serine	5.9
Threonine	2.8
Tyrosine	2.7
Valine	5.3

[a]Source: Rombouts et al 2009

Create Exceptional™

APPENDIX B

Molecular weight distribution of wheat gluten by size exclusion chromatography with ultraviolet detection. Left side of the curve – Polymeric Proteins; Right side of the curve – Monomeric Proteins.



APPENDIX C

Amino acid composition of ProTerra® 1200.

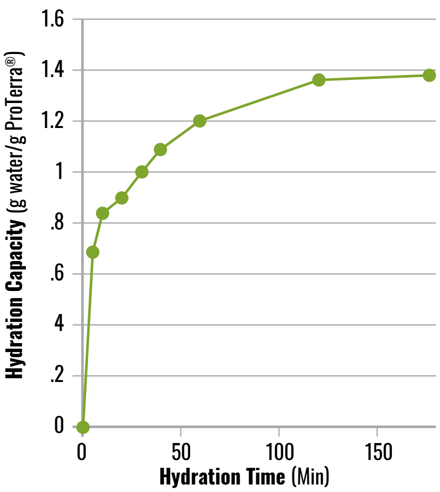
%	Amino Acid
1.99	Aspartic Acid
1.51	Threonine
2.75	Serine
22.23	Glutamic Acid
8.05	Proline
2.05	Glycine
1.56	Alanine
2.26	Valine
2.22	Isoleucine
4.12	Leucine
2.03	Tyrosine
2.99	Phenylalanine
0.95	Lysine
1.23	Histidine
2.04	Arginine
1.12	Cysteine
1.00	Methionine
0.67	Tryptophan

[a]Moisture = 7.9%; Protein = 64.0% (N x 6.25)

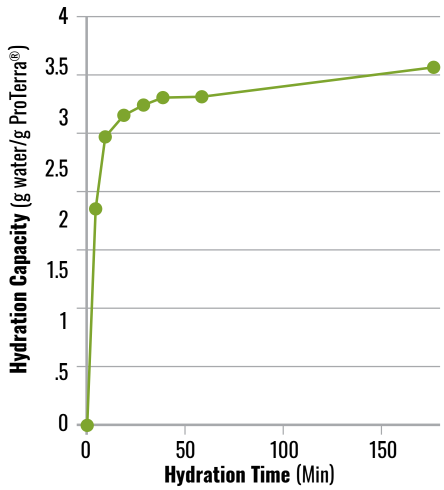
APPENDIX D

Hydration curves of ProTerra® products using ambient water temperature (70 -72°F or 21-22°C)

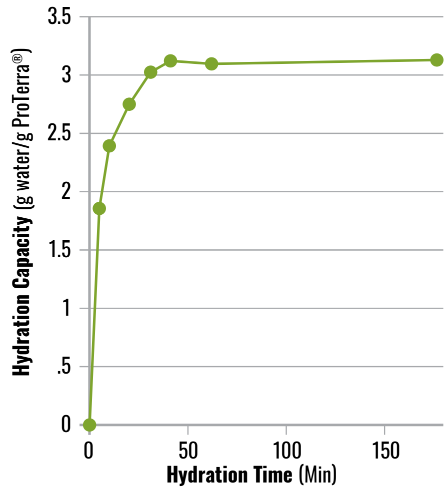
ProTerra® 1150M



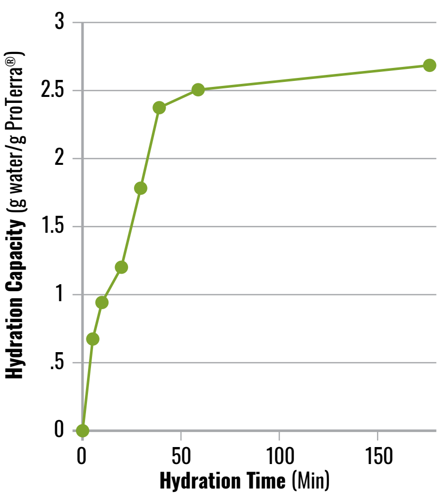
ProTerra® 1100



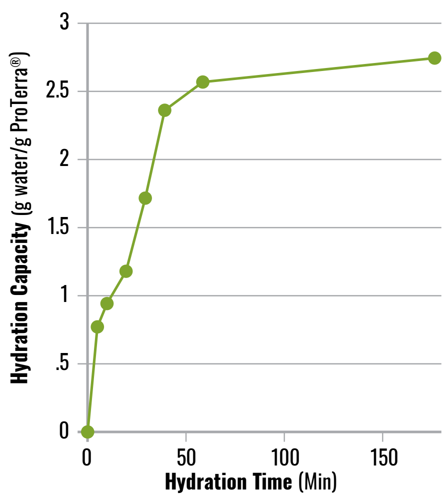
ProTerra® 1100C



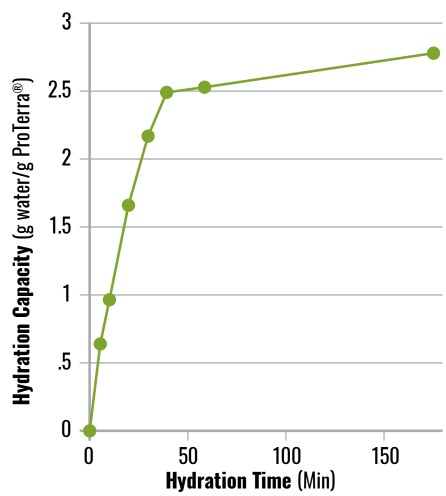
ProTerra® 1300



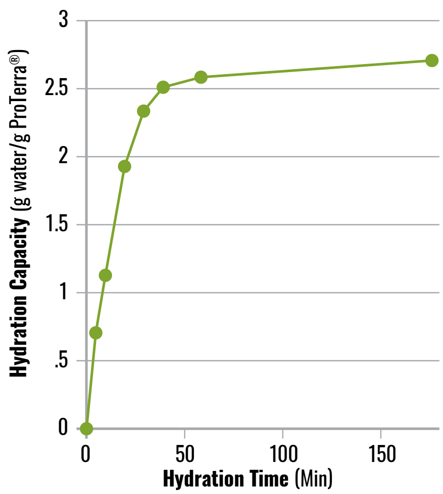
ProTerra® 1300C



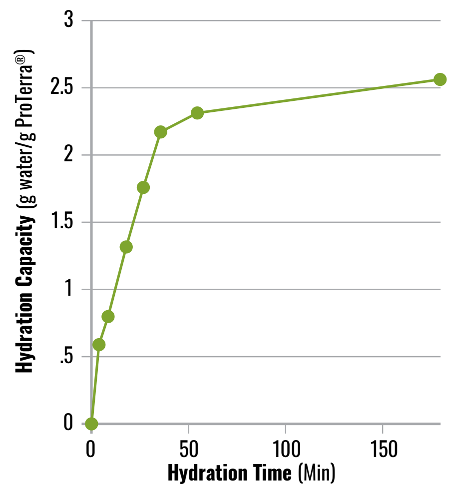
ProTerra® 1350



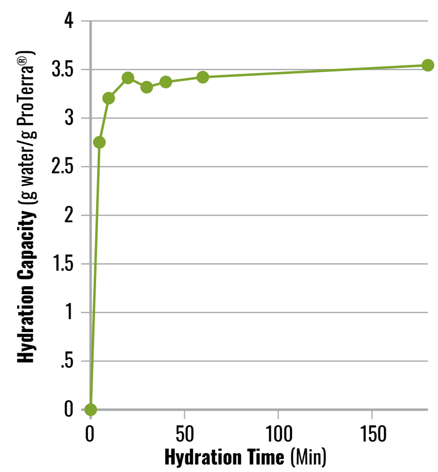
ProTerra® 1350C



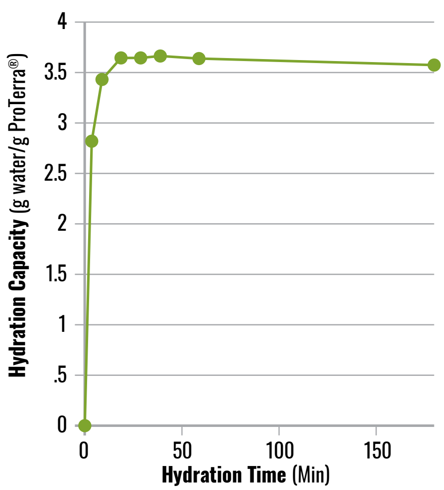
ProTerra® 1350DC



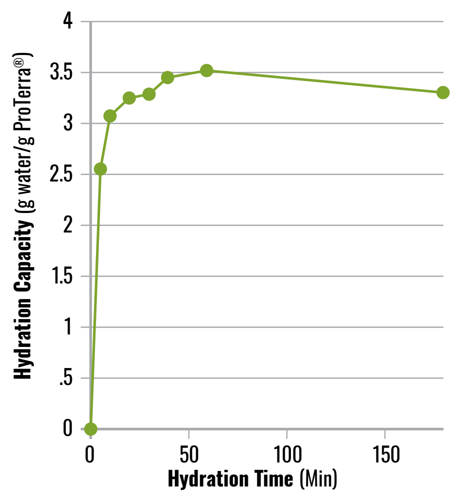
ProTerra® 1200



ProTerra® 1200C



ProTerra® 1200DC



APPENDIX E

Appearance of different ProTerra® products in dry state (before hydration), after hydration, and after hydration then heating to 250°F or 121°C (20 psi) for 10 minutes

1150M

Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

1100

Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

1100C

Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

1300

Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

1300C

Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

1350

Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

APPENDIX E ▶ Continued

1350C

Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

1350DC

Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

1200

Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

APPENDIX E ▶ Continued

1200C

Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

1200DC

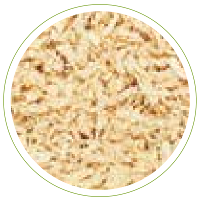
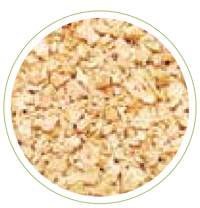
Dry
(before hydration)

Hydrated

Hydrated then heated
to 250°F or 121°C (20 psi) for 10 min

APPENDIX F

PROTERRA® WHEAT PROTEIN APPLICATIONS AND CHARACTERISTICS GUIDE

	APPLICATIONS	INGREDIENT CHARACTERISTICS	TYPICAL HYDRATION TIME (AT 22° C)	TYPICAL HYDRATION RATIO (AT 22° C)	PROTEIN (N X 6.25)	AVAILABLE COLORS*	TYPICAL DIMENSIONS, DRY
PROTERRA® 1200 SERIES 	Vegetarian products and shredded meats	Fibrous shreds	10 minutes	3.3:1.0	60%	LT C DC	Irregular shreds
PROTERRA® 1300 SERIES 	Vegetarian products, ground meats, shredded meats and soups	Strong fibrous material/ shreddable when hydrated	40 minutes	2.6:1.0	66%	LT C	9mm wide 11mm long 2mm thick
PROTERRA® 1350 SERIES 	Vegetarian products, ground meats and shredded meats	Strong fibrous material/ shreddable when hydrated	40 minutes	2.6:1.0	63%	LT C DC	17mm wide 25mm long 3mm thick
PROTERRA® 1100 SERIES 	Vegetarian products, reformed meats and ground meats	Semi-firm granules	15 minutes	3.0:1.0	65%	LT C	6mm granule
PROTERRA® 1150M SERIES 	Vegetarian products, reformed meats and ground meats	Firm granules	60 minutes	1.4:1.0	77%	M	6mm granule

*KEY CODE	COLOR DRY	COLOR HYDRATED	INGREDIENT RESEMBLES
LT	LIGHT TAN	OFF WHITE	CHICKEN AND SEAFOOD
C	CARAMEL	LIGHT BROWN	CHICKEN AND PORK
DC	DARK CARAMEL	DARK BROWN	BEEF
M	MALT	BROWN	BEEF

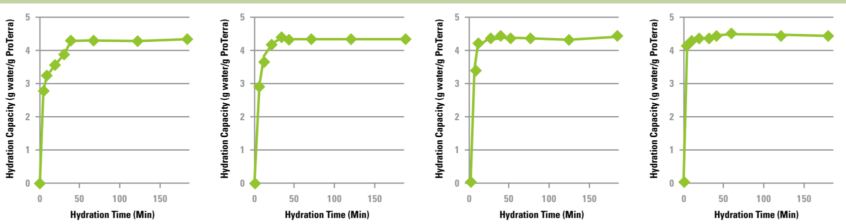
All of our proteins are Non-GMO Project Verified (except caramel-colored ProTerra®)

PROTERRA® PEA PROTEIN APPLICATIONS AND CHARACTERISTICS GUIDE

	APPLICATIONS	INGREDIENT CHARACTERISTICS	TYPICAL HYDRATION TIME (AT 22° C)	TYPICAL HYDRATION RATIO (AT 22° C)	PROTEIN (N X 6.25)	AVAILABLE COLORS*	TYPICAL DIMENSIONS, DRY
PROTERRA® 2200 SERIES 	Vegetarian products, shredded meats and extended (blended) products	Fibrous shreds, easy to incorporate	30 minutes	4.3:1.0	75% min.	LT	Irregular shredded fiber
PROTERRA® 2350 SERIES 	Vegetarian products, shredded meats, ground meats and extended (blended) products	Can be chopped to desired size, shreddable when hydrated	60 minutes	4.5:1.0	75% min.	LT	Irregular flat chips

PROTERRA® PEA PROTEIN HYDRATION PROPERTIES

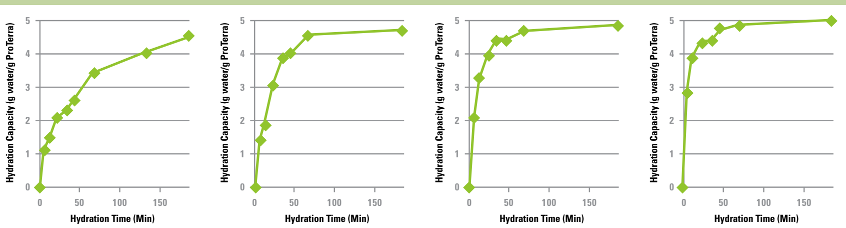
PROTERRA® 2200 SERIES



At 5° C | At 22° C | At 37° C | At 50° C

TEMPERATURE (°C)	HYDRATION CAPACITY (G WATER/G TEXTURED PEA PROTEIN)	HYDRATION TIME (MIN)
5°C	4.2-4.3	40
22°C	4.3	30
37°C	4.3	20
50°C	4.3	10

PROTERRA® 2350 SERIES



At 5° C | At 22° C | At 37° C | At 50° C

TEMPERATURE (°C)	HYDRATION CAPACITY (G WATER/G TEXTURED PEA PROTEIN)	HYDRATION TIME (MIN)
5°C	4.6	180
22°C	4.5	60
37°C	4.6	60
50°C	4.7	40

*KEY CODE	COLOR DRY	COLOR HYDRATED	INGREDIENT RESEMBLES
LT	LIGHT TAN	OFF WHITE	CHICKEN AND SEAFOOD
C	CARAMEL	LIGHT BROWN	CHICKEN AND PORK
DC	DARK CARAMEL	DARK BROWN	BEEF
M	MALT	BROWN	BEEF

NON GMO Project VERIFIED nongmoproject.org

All of our proteins are Non-GMO Project Verified (except caramel-colored ProTerra®)

LET'S START SOMETHING

Call 866.547.2122 to learn more about the many ways MGP can help turn your ideas into reality.

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