Arise®
WHEAT PROTEIN ISOLATES

TECHNICAL SPECIFICATIONS

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MGP®
Create Exceptional™

Arise® WHEAT PROTEIN ISOLATES

TECHNICAL SPECIFICATIONS

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Arise® WHEAT PROTEIN ISOLATES | TECHNICAL SPECIFICATIONS

MGP® Create Exceptional™

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ABOUT MGP

Founded in 1941 in Atchison, Kansas, under the original name of Midwest Solvents Company, but now MGP Ingredients Inc., the company has been serving the food and alcohol industry for nearly eight decades. Today, MGP, together with its subsidiaries, is a leading producer and supplier of premium distilled spirits and specialty wheat proteins and starch food ingredients. It operates in two segments, Distillery Products and Ingredient Solutions. The Distillery Products segment provides food grade alcohol for beverage applications that include bourbon and rye whiskeys, as well as grain neutral spirits, including vodka and gin; and food grade industrial alcohol, which is used as an ingredient in foods, personal care products, cleaning solutions, pharmaceuticals, and various other products. This segment also provides fuel grade alcohol for blending with gasoline and distillery co-products, such as distillers feed and corn oil.

The Ingredient Solutions segment provides specialty wheat proteins and starch food ingredients for use in a diverse range of food products. Through the years, MGP has pioneered the development of these specialty food ingredients, resulting in a wide range of superior ingredient solutions for a host of food product applications. These solutions provide a multitude of functions and benefits for bakery and prepared foods, including processing improvements, moisture management, shelf-life extension, fiber fortification, calorie reduction, fat reduction and texture enhancement. The company sells its products directly or through distributors to manufacturers and processors of finished packaged goods or to bakeries around the world.

MGP's applications scientists work closely with our sales team to provide technical support to customers by addressing specific needs and/or helping define the value and performance of our ingredients for targeted uses. They are available to work directly with customers at their facilities or at our fully equipped, state-of-the-art Technical Innovation Center to assist in the development of product formulations. Meanwhile, our research scientists direct their expertise and resources toward the development and refinement of new and innovative ingredients for the future.

In short, we recognize that our customers want a reliable partner who can effectively support their objectives and boost product success. With our specialty ingredient solutions, decades of experience and technical know-how, we at MGP are equipped to meet customers' needs.

PROTEIN TRENDS AND MARKET SIZE

In a 2017 consumer survey on the healthfulness of nutrients by the International Food Information Council (IFIC) Foundation, protein from plant sources ranked 4th as the most healthful nutrient behind whole grains, fiber and vitamin D while animal protein ranked 9th. The same survey in 2018 gave almost the same results except that animal protein was now ranked the 8th most healthful nutrient. In the 2019 IFIC survey, protein from plant sources jumped to the 3rd most healthful nutrient behind whole grains and fiber whereas animal protein lagged behind in 10th place. Predictably and riding on its perceived health halo, plant proteins (3rd) continued to rank higher in healthfulness than animal proteins (9th) in the 2020 food and health survey by IFIC.

The global protein ingredients market including both animal and plant proteins is forecasted to grow from $41.9 billion in 2017 to $65.3 billion by the end of 2024, which is a compounded annual growth rate (CAGR) of 6.54% (https://www.researchandmarkets.com/publication/m1l8n3l/4745820). The wheat protein market size is predicted to exceed $2.7 billion by 2024 according to Global Insights, Inc., which is a CAGR of 3% over the period of 2017-2023 (https://www.researchandmarkets.com/publication/m3wsrwa/4447288). The wheat-protein market is segmented into wheat gluten, wheat protein isolate, textured wheat protein and wheat protein hydrolysate.

WHEAT GLUTEN PROTEINS

Proteins are diverse polymeric molecules that are assembled fundamentally from 20 different "blocks" termed amino acids. Living organisms rely on proteins to carry out metabolic processes and to construct body parts. The ***primary*** structure of a protein at the molecular level is a long chain of amino acids, usually numbering in the hundreds, connected together in a unique sequence by peptide bonds. Protein chains can exhibit ***secondary*** structure caused by weak but repetitive attractive forces within or between chains leading to a helical chain or to a collection of chains in a pleated-sheet arrangement. ***Tertiary*** molecular structure of a protein occurs when a protein chain folds into a unique three-dimensional shape in response to a multitude of weak attractive or repulsive forces, or to strong interconnecting bonds between chains. Finally, ***quaternary*** structure occurs when two or more protein molecules associate together through physical attraction to form a complex. The primary to quaternary structural features of proteins explains how they are able to perform their diverse functions.

The proteins present in animals are assembled by metabolic processes that begin with the ingestion of dietary protein in a food or feed. The ingested protein is digested to release amino acids, which are incorporated either directly by the animal into its body's proteins, or which are further broken down to give primary metabolites that are subsequently assembled into amino acids or other life-essential molecules. Animals are incapable of producing all 20 amino acids needed in their bodies by the assembling of primary metabolites. The amino acids that cannot be biosynthesized in an animal from primary metabolites must be present in the animal's diet in sufficient quantity to satisfy its metabolic needs. Those amino acids are termed essential amino acids for that animal. On the other hand, non-essential amino acids are those which can be biosynthesized in an animal from primary metabolites. The primary metabolites used by an animal to biosynthesize non-essential amino acids arise from ingested protein. For that reason, animals require a sufficient intake of protein to satisfy both its essential and non-essential protein needs.

Wheat is a major source of ingested protein for humans but, like rye and barley, it is deficient in two essential amino acids when used as food. They contain low levels of lysine (the first limiting amino acid) and to a lesser extent, threonine (the second limiting amino acid) when compared to World Health Organization requirements of essential amino acids for humans.

In 1745, Giacomo Beccari, Professor of Chemistry at the University of Bologna, first reported the preparations of a water-insoluble protein fraction from wheat flour, which he called "glutinis". More than a century later, Thomas Burr Osborne, a biochemist at the Connecticut Agricultural Experiment Station, systematically classified proteins into groups on the basis of their solubility after sequential extraction: albumins (water), globulins (dilute salt), prolamins (alcohol-water mixtures), and glutelins (dilute acid or alkali).

WHEAT GLUTEN PROTEINS ▶ Continued

To the current day, vital wheat gluten is still isolated from wheat flour by a dough washing procedure in which the gluten agglomerates into low-density particles in an aqueous slurry of wheat starch. In rheology terms, hydrated wheat gluten is termed a viscoelastic substance, where elasticity is the property of a solid that deforms instantly upon application of stress and returns to its original shape instantly upon removal of that stress, and where viscosity is the property of a fluid which flows instantly upon application of a stress and which does not return to its original shape upon removal of the stress. A precise balance between these two properties in a wheat dough is necessary in the production of quality yeast-leavened bakery products. The viscoelastic property of wheat gluten allows the forming of a continuous dispersed network of protein in a dough that retains gas bubbles and rises, giving volume to bread, and which provides after baking a soft crumb texture that is unique and cannot be duplicated by other animal- or plant-based proteins.

Wheat gluten is classically divided into two functionally significant fractions: glutenin, insoluble in alcohol-water mixtures, and gliadin, soluble in alcohol-water mixtures. The elastic property of wheat gluten is due to the glutenin fraction, while the viscous property (plasticity and extensibility) of dough is due to the gliadin fraction. The relative proportions of gliadin and glutenin found in gluten affect dough properties; an increased proportion of glutenin imparts increased dough strength. Highly elastic doughs are crucial for bread making, especially hearth breads, whereas extensible doughs are essential for making crackers and cookies. The strength/extensibility requirements of doughs for tortillas, flat breads, and wheat-salt noodles fall between those extremes.

Wheat flour typically contains 8-18% protein depending upon whether the class of wheat is soft, hard or durum. The majority of protein occurring in wheat kernels is storage protein that forms a continuous matrix surrounding wheat starch granules. The strength of association between the matrix protein in a wheat kernel and its starch granules is correlated with grain hardness. Of the total protein in wheat flour, 75-80% represent gluten-forming proteins consisting of about one-half of gliadins (monomeric proteins) and the other half of glutenins (polymeric proteins) as shown by size-exclusion chromatography **(Fig. 1)**.

The gliadin fraction is not a singular protein but comprised of structurally different groups called α-, β-, γ-and ω-gliadins with molecular weights ranging from 30,000-74,000 daltons **(Fig. 1)**. The glutenin fraction is comprised of individual polypeptides or subunits that are linked together by inter-molecular disulfide bonds to form a macro-protein molecule of extraordinarily high molecular weight. When treated with a suitable reducing agent to cleave the disulfide bonds, the glutenin proteins can be separated into low-molecular weight glutenin subunits (80%) with molecular weights of 30,000-55,000 daltons and high-molecular weight glutenin subunits (20%) with molecular weights of 80,000-160,000 daltons. 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 high-molecular weight glutenin subunits form a distinct group and 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.

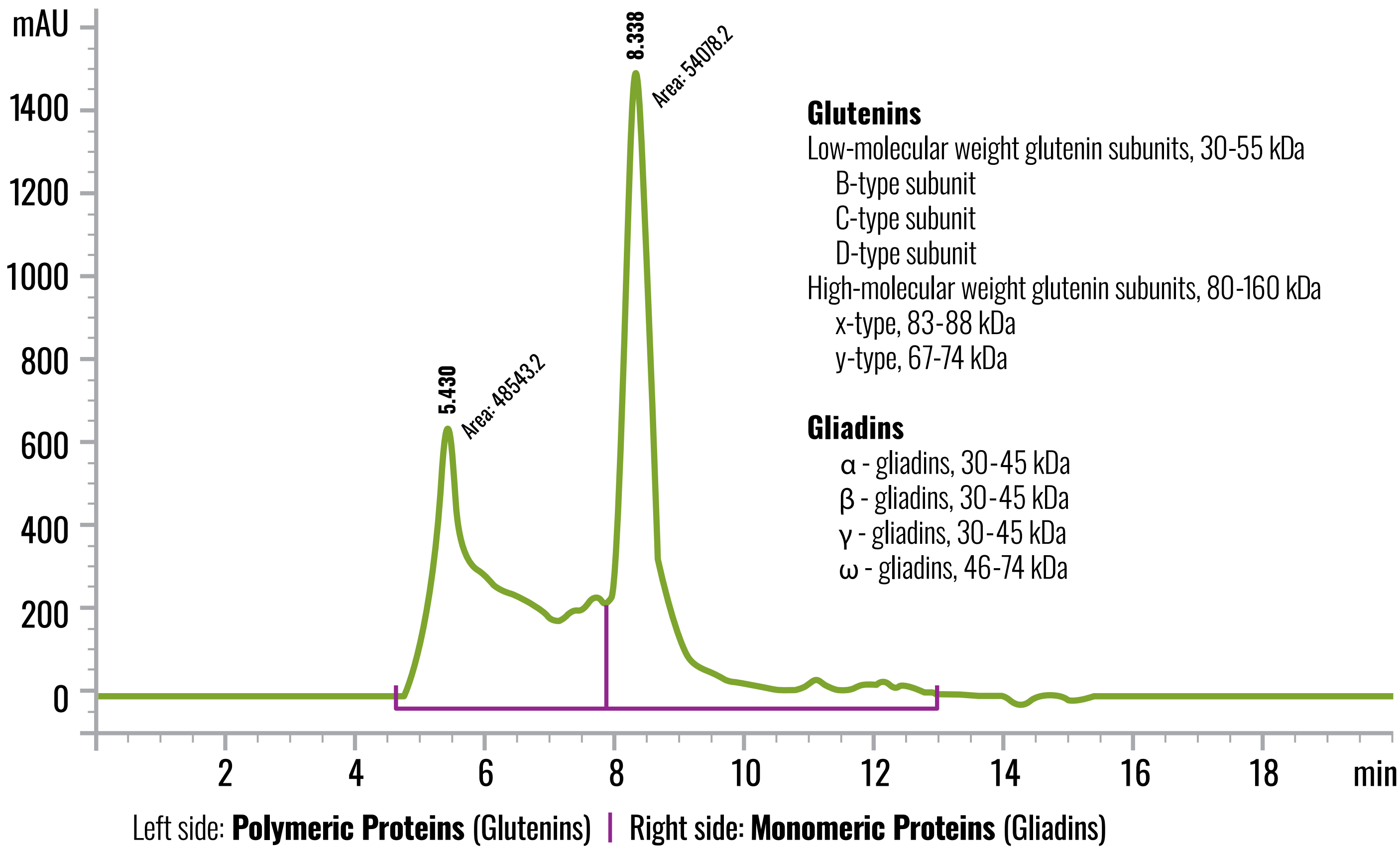
WHEAT PROTEIN ISOLATES

Wheat is an economical source of nutritionally important macronutrients including protein and carbohydrate (dietary fiber and food energy) as well as several micronutrients and bioactive substances. Although frequently regarded as a source of calories, wheat also provides significant amounts of protein to the diet. The three principal amino acids of wheat gluten are glutamine, proline and leucine **(Table 1, Appendix A)**. Isolated wheat starch and gluten (protein) and their modified or specialty versions are standard ingredients in the food industry today.

The U.S. Food and Drug Administration's (FDA) Code of Federal Regulations defines wheat gluten (CAS Reg. No. 8002-80-0) as the principal protein component of wheat and consisting mainly of gliadin and glutenin (21 CFR 184.1322). Wheat gluten is obtained by hydrating wheat flour and mechanically processing the sticky mass to separate the wheat gluten from the starch and other flour components.

By comparison, wheat gluten is defined in the Food Chemicals Codex as the water-insoluble protein complex

Figure 1. *Molecular weight distribution of wheat gluten proteins by SEC-HPLC and composition of the protein fractions.*



obtained by water extraction of wheat or wheat flour. It is described as a cream to light-tan, free-flowing powder, and is considered to be soluble in alkalies and partly soluble in alcohol and dilute acids. Its protein content is not less than 71%, calculated on dry basis. Vital wheat gluten, the term commonly used in the baking industry, is characterized by high viscoelasticity when hydrated, whereas devitalized wheat gluten has lost this characteristic due to denaturation by heat or treatment with a solvent.

Vital wheat gluten is also described under Codex standards for Wheat Protein Products (CODEX STAN 163-1987, Rev. 1-2001). Vital wheat gluten is characterized by its property of high viscoelasticity in a hydrated state, whereas devitalized wheat gluten is characterized by its reduced property of viscoelasticity when hydrated due to denaturation. The protein content of each is reported to be 80% or higher on a dry weight basis using a factor of N x 6.25.

A product derived from wheat gluten is wheat protein isolate that has dual descriptions in the Food Chemicals Codex. First, it is produced by acidic deamidation of gluten that converts glutamine and asparagine in the protein to their nonaminated derivatives, glutamic acid and aspartic acid, followed by several purification measures. Second, it is produced by solubilization of gluten in an acidic or alkaline medium, and the dissolved protein is then separated and purified by filtration or centrifugation. The protein content is not less than 75%, calculated on dry basis and using a nitrogen-to-protein conversion factor of 5.7. The patent literature shows some methods and processes for the production of wheat protein isolate as described in U.S. Patent 8309152, U.S. Patent 8551544, and U.S. Patent 8758845. Other inventive processes are described in U.S. Patent Application Publication Numbers US20140142285A1, US20150250204A1, US20190142049A1, and US20190142029A1.

WHEAT PROTEIN ISOLATES

The properties and functionality of wheat gluten (protein) can be altered to suit its intended end-use applications. Relevant methods of protein modification applicable to wheat proteins and other protein sources include partial and progressive protease hydrolysis, acid modification (deamidation), cross-linking, and oxidation/reduction reactions.

Partial protease hydrolysis of gluten results in an increase of water solubility, improvement of moisture absorption and water binding, improvement of emulsifying properties, and an increase in foam stability. On the other hand, progressive protease hydrolysis leads to the formation of an increasing level of bitter peptides as a result of the exposure of hydrophobic amino acid residues near the carboxyl terminal in the polypeptide products. Complete acid hydrolysis of proteins to amino acids is accomplished by treatment with a high concentration of hydrochloric acid at high temperature. Also at a high temperature, but with a relatively low concentration of hydrochloric acid, gluten protein undergoes deamidation, a modification reaction which converts glutamine and asparagine residues in the polypeptide chain to glutamic acid and aspartic acid, respectively.

The transglutaminase enzyme catalyzes the cross-linking of proteins through the formation of intra- and inter-molecular bonds between glutamine and lysine residues. Treatment with oxidants like potassium bromate, potassium iodate, ascorbic acid, and azodicarbonamide or glucose oxidase results in oxidation of sulfhydryl groups in wheat protein to form disulfide cross-links. Cross-linking/oxidation of a wheat dough produces a strengthening effect, whereas reduction of disulfide cross-links in gluten protein decreases the strength of a dough. The reduction of disulfide cross-links by addition of L-cysteine, glutathione, yeast, yeast extract or sodium bisulfite not only breaks disulfide cross-linkages but also releases free sulfhydryl groups that can further weaken a dough through disulfide-sulfhydryl interchange reactions on gluten proteins.
The reduction reaction on gluten proteins leads to increased dough extensibility.

As an aside, the "L" in L-cysteine specifies the exact 3-dimensional shape of its molecule. A cysteine molecule exists in two shapes that are mirror images of each other, like one's left and right hands. Naturally-occurring amino acids are almost universally the L-form. Un-natural D-amino acids are misshaped biologically and fail to perform almost all biological functions.

The sulfhydryl groups and disulfide bonds in wheat flour proteins are involved in oxidation-reduction reactions and in interchange reactions that have significant effects on the structure of gluten proteins. Thus, they play an important role in dough rheology and breadmaking. The baking industry traditionally relies

ARISE® FAMILY OF WHEAT PROTEIN ISOLATES

on chemical-based dough strengtheners (oxidants) and relaxers (reducing agents). Examples of these oxidants are ascorbic acid (vitamin C), potassium bromate, potassium iodate, and azodicarbonamide, whereas the reducing agents are sodium bisulfite, L-cysteine, glutathione, yeast, yeast extracts, sorbic acid and fumaric acid among others. Dough relaxers (or reducing agents), which break disulfide bonds, are added to wheat-based doughs to improve its extensibility, sheeting properties and overall machinability.

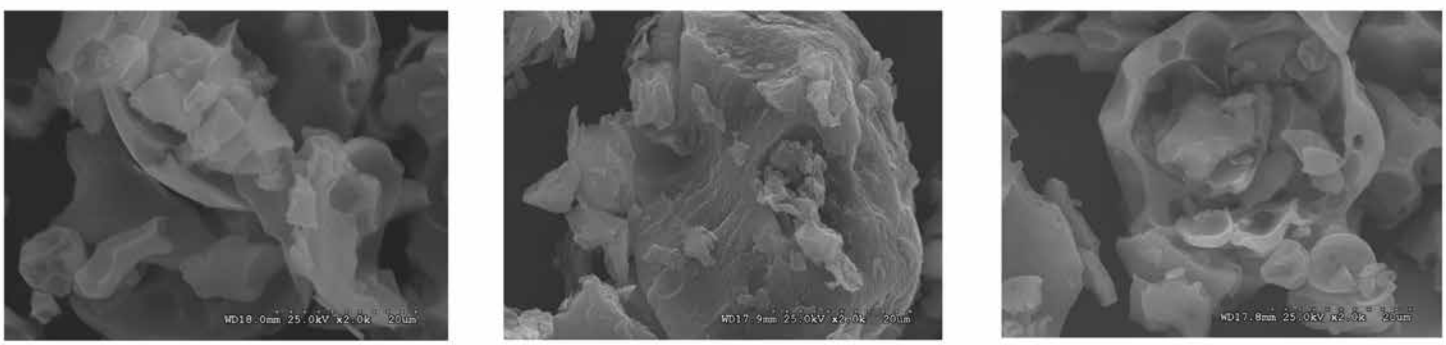
L-cysteine is a unique amino acid because it has a sulfhydryl group at the end of the molecule. Currently, it is available commercially from a vegan, non-GMO source. It is a reducing agent (i.e. cleaves disulfide bonds in proteins) and belongs to a type of dough conditioner used to reduce mixing time and improve extensibility. L-cysteine is used in baking operations especially in high-speed baking to adjust for flour variation, reduce mixing time, lower energy input, improve machinability, enhance loaf volume, and to increase throughput.

Due to the clean label trend, consumers are expressing aversion to chemical additives and are preferring "natural" ingredients. The Arise® family of wheat protein isolates were developed to function as protein-based dough relaxers (and sometimes as strengtheners) with similar functionalities as L-cysteine, glutathione, yeast, and yeast extracts (non-leavening yeast). MGP Ingredients Inc. produces six types of wheat protein isolates, namely Arise® 5000, Arise® 5500, Arise® 6000, Arise® 8000, Arise® 8100, and Arise® 8200. They are all certified non-GMO Project Verified and their contrasting properties are shown in Table 2. Their nutritional contributions per 100 grams are displayed in Table 3 (Appendix A). These wheat protein isolates can be used in conventional or high-protein dough formulations to obtain desirable relaxation or strengthening properties. All are available as a light tan powder with 85-90% or more protein content and with neutral or slightly acidic pH. When viewed under a scanning electron microscope, Arise® 5000 and Arise® 6000 demonstrate irregular shapes of their particles with a wide distribution of sizes whereas Arise® 5500 appears to also have a distribution of sizes, but with a dense 3-dimensional shape (Fig. 2).

Arise® 5000, when hydrated, displays the most extensible and the least elastic properties (Table 2). The appearance of hydrated Arise® 5000 is shown in Fig. 3 depicting its sticky, cohesive and extensible properties. Due to its low pH (4.0-4.5) when hydrated in excess water, Arise® 5000 becomes dispersible/soluble in water. It is sulfite-treated and its protein content is equal to or more than 90% (N x 6.25, dry basis). Similar to wheat gluten, the major amino acids of Arise® 5000 are glutamine, proline and leucine (Table 4).

Arise® 5500 is similar in its production process and functional properties as Arise® 5000 except the drying step in Arise® 5500 leads to a heavier bulk density of its dried powder. Its pH, protein content and extensibility properties when hydrated are comparable to Arise® 5000 (Fig. 3).

Figure 2. *Appearance of Arise® 5000, Arise® 5500 and Arise® 6000 when viewed under a scanning electron microscope at 2000X magnification.*



Arise® 5000 | Arise® 5500 | Arise® 6000

Table 2. *Comparison of properties of the different Arise® wheat protein isolate products.*

Wheat Protein Isolate	Treatment	Protein, % (N x 6.25, d.b.)	pH	Hydrated Properties
Arise® 5000	Sulfite	≥90%	4.0-4.5	Most extensible
Arise® 5500*	Sulfite	≥90%	4.0-4.5	Most extensible
Arise® 6000	Sulfite	≥85%	6.2-7.0	Less extensible than Arise® 5000 and Arise® 5500
Arise® 8000	None	≥90%	6.0-7.0	Most elastic
Arise® 8100	L-Cysteine	≥90%	4.0-4.5	Similar extensibility as Arise® 5000 and Arise® 5500
Arise® 8200	L-Cysteine	≥85%	6.2-7.0	Less extensible than Arise® 8100

*The production of Arise® 5500 is similar to Arise® 5000 except for the different drying conditions of the former resulting in higher particle density.

ARISE® FAMILY OF WHEAT PROTEIN ISOLATES ▶ Continued

Key Points of Arise® 5000:

- Decreases dough mix time
- Causes slackening effect on the dough out of the mixer, but dough recovers to optimum at the make-up stage
- Increases dough extensibility
- Increases dough machinability
- Increases bread volume
- Produces internal structure (grain) and crumb firmness comparable to the control bread
- Reduces microwave-induced toughness of pup loaf bread
- Results in donut size and cell structure comparable to the control donut
- Reduces pastiness of buttermilk bisquits without adding toughness
- Increases flour tortilla diameter and rollability scores
- Improves shelf-life of flour tortillas
- Improves overall bread score and crumb softness of frozen doughs
- Non-GMO Project Verified

When hydrated, Arise® 6000 demonstrates less extensible and medium elastic properties (Fig. 4) than Arise® 5000 and Arise® 5500. It is sulfite-treated and its protein content is a minimum of 85% (N x 6.25, dry basis). Upon hydration, the pH of Arise® 6000 is about neutral.

Arise® 8000 is a high-purity wheat protein isolate with no intentionally incorporated additives and containing a minimum of 90% protein (N x 6.25, dry basis). It is the most elastic protein (Fig. 5) of the Arise® series, acts as a dough strengthener, and is suitable for clean label applications. The hydrated pH of Arise® 8000 is approximately neutral.

Clean label versions of Arise® 5000 and Arise® 6000 were developed by eliminating the sulfite treatment and instead treating with L-cysteine from a vegan, non-GMO source. The safe use of L-cysteine in foods is described in 21 CFR 172.320. Modification of the properties of wheat protein is accomplished with a non-GMO L-cysteine that is derived by fermentation of a vegan substrate. L-cysteine-treated Arise® 8100 is the clean label equivalent of sulfite-treated Arise® 5000. It has similar pH, protein content and extensibility properties compared to that of Arise® 5000 and Arise® 5500 (Fig. 3).

L-cysteine-treated Arise® 8200 is the clean label equivalent of sulfite-treated Arise® 6000. Its protein content is equal to or more than 85% (N x 6.25, dry basis) with pH near neutral. It has extensibility and elasticity properties comparable to Arise® 6000 (Fig. 4).

The extensibility and elasticity properties of hydrated Arise® 5000, Arise® 5500, Arise® 6000, Arise® 8000, Arise® 8100 and Arise® 8200 are compared to vital wheat gluten schematically in Fig. 6. The curves in Fig. 7 depict some significant and subtle differences in mixing characteristics of these six Arise® wheat protein isolates. Except for Arise® 8000, the other five Arise® protein isolates show rapid hydration attaining a peak (i.e. point of minimum mobility) in about a minute or less. The hydrated properties of Arise® wheat protein isolates as determined on several dough-rheology testing instruments are reported in this booklet under the section on Functionality in Dough Systems.

Key Points of Arise® 6000:

- Increases dough extensibility
- Increases water absorption
- Decreases dough mixing time
- Increases loaf volume of bread
- Causes slackening effect on the dough out of the mixer, but dough recovers to optimum at the make-up stage
- Produces internal structure (grain) and crumb firmness comparable to the control bread
- Increases firmness of pasta
- Replaces egg whites in pasta formulations
- Increases flour tortilla diameter and rollability scores
- Improves shelf-life of flour tortillas
- Non-GMO Project Verified

Figure 3. *Appearance of hydrated Arise® 5000, Arise® 5500 and Arise® 8100 showing its sticky, cohesive and extensible properties (1 part Arise® to 2 parts water).*

Figure 4. *Appearance of hydrated Arise® 6000 and Arise® 8200 showing less extensible, medium elastic properties (1 part Arise® to 2 parts water).*

Figure 5. *Appearance of hydrated Arise® 8000 showing its elastic properties (1 part Arise® 8000 to 2 parts water).*

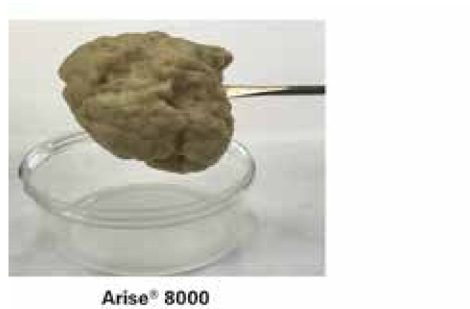


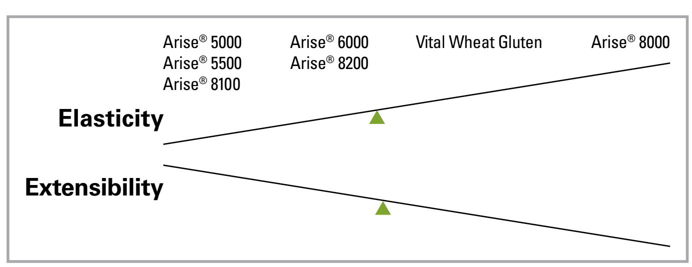
Table 4. *Amino acid composition of Arise® 5000.*

Amino Acid	%
Aspartic Acid	2.55
Threonine	1.92
Serine	3.53
Glutamic Acid	31.78
Proline	10.39
Glycine	2.67
Alanine	2.03
Valine	3.01
Isoleucine	3.02
Leucine	5.55
Tyrosine	2.73
Phenylalanine	4.13
Lysine	1.90
Histidine	1.71
Arginine	2.62
Cysteine	1.97
Methionine	1.31
Tryptophan	0.16

Key Points of Arise® 5500:

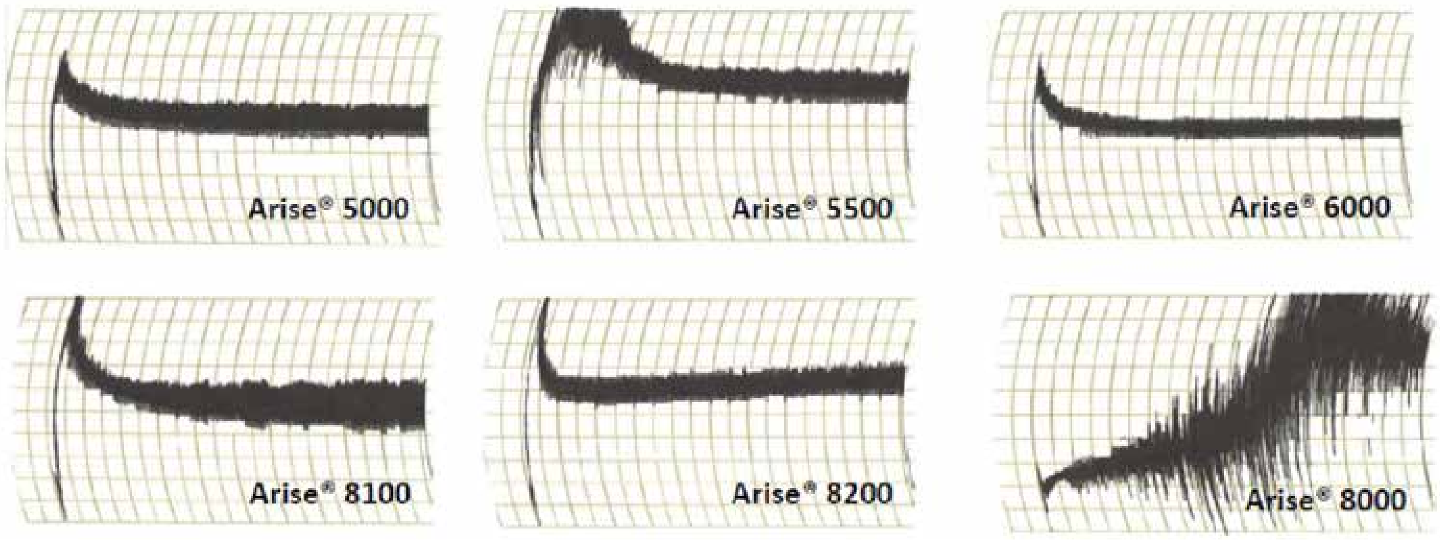
- Highest particle density of all Arise® wheat protein isolates
- Ease of handling and less prone to dustiness
- Increases dough extensibility
- Decreases dough mix time
- Comparable baking performance as Arise® 5000
- Non-GMO Project Verified

Figure 6. *Comparative ranking of the extent of extensibility and elasticity of six Arise® wheat protein isolates and vital wheat gluten.*



ARISE® FAMILY OF WHEAT PROTEIN ISOLATES ▸ Continued

Figure 7. *Mixing curves* of the different Arise® wheat protein isolate products.*



***Wheat Protein Isolate** : **Wheat Starch** : **Water** ratio during the mixograph test:

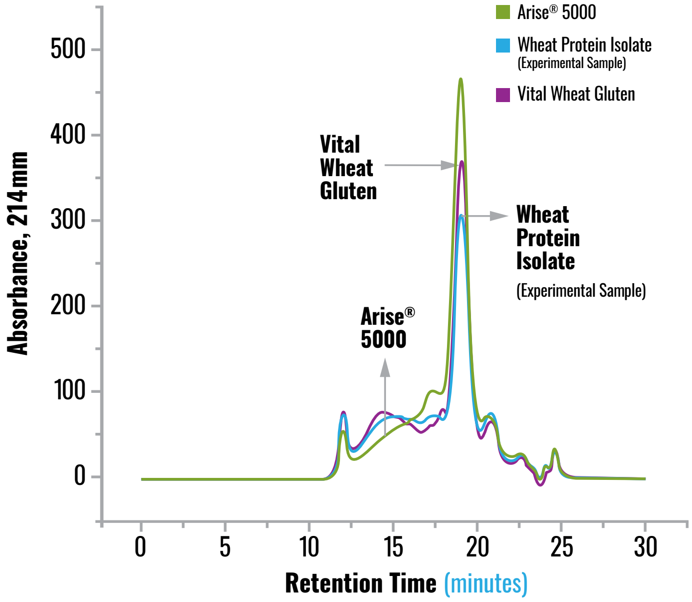
Arise® 5000 – 5:5:5
Arise® 5500 – 5:5:5
Arise® 6000 – 5:5:6.7
Arise® 8100 – 5:5:5
Arise® 8200 – 5:5:6.7
Arise® 8000 – 2.9:7.1:8.6

Typical molecular weight distributions of wheat protein isolates compared to vital wheat gluten are displayed in the SEC-HPLC curves in **Fig. 8**. Compared to vital wheat gluten, Arise® 5000 demonstrates a reduction of the polymeric glutenin proteins and an increase of low molecular weight glutenin proteins.

MGP's vital wheat gluten and all six Arise® wheat protein isolates are certified as Non-GMO Project Verified. GMO stands for genetically modified organism. The Non-GMO Project, a non-profit organization, offers North America's only third- party verification and labeling for non-GMO food and food ingredients. This organization verifies products with the goal of preserving and building the non-GMO food supply and educating consumers on their non-GMO choices.

Wheat (gluten) protein is unique as it is the only plant-based protein capable of forming a viscoelastic dough upon hydration capable of trapping leavening gases, supporting gas cells, giving volume to bread and providing a soft spongy texture. Pulse grains from pea, lentil, bean and chickpea contain high amounts of protein, and a pulse protein gives benefits when mixed

Figure 8. *Molecular weight distribution profile by SEC-HPLC of vital wheat gluten and wheat protein isolates.*

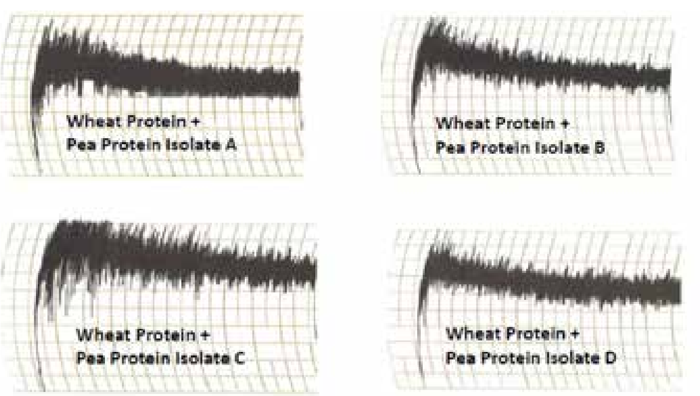


WHEAT PROTEIN/PULSE PROTEIN BLENDS

with wheat protein even though pulse protein is devoid of strong elastic properties. Pulses provide a sustainable source of gluten-free protein that contains a balanced amino acid composition. A mixture of pulse and wheat proteins gives a product with improved nutritional value compared to either protein alone. The amino acids deficient in gluten for humans are bolstered by those in pulse protein and vice versa, which is described as the complementary effect of blending. In one particular mixture, wheat and pea differ in composition and functional properties of their proteins and their protein fractions. Based on Osborne's solubility fractionation, wheat protein is primarily comprised of 45% glutelins (glutenins) and 40% prolamins (gliadins) with minor amounts of albumins (5%) and globulins (10%). By contrast, pea protein's major components are 49-70% globulins (legumin and vicilin) and 15-25% albumins with lower amounts of glutelins (11%) and prolamins (5%). Due to these compositional differences that lead to nutritional benefits, it is interesting that a combination of wheat and pea proteins may possibly have some synergies that exhibits special functional properties.

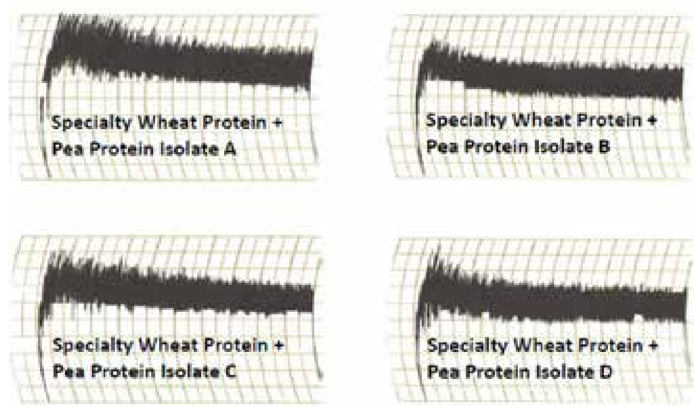
A mixture of wheat protein and pea protein isolates from four commercial sources showed mixing characteristics **(Fig. 9)** quite different compared to those of Arise® wheat protein isolates alone **(Fig. 7)**. This protein blend free of processing aids exhibits a rapid rise in its mixing curve to reach a peak followed thereafter by a stable curve. Subtle differences in the appearance of the mixing curve were observed depending on which of the four sources of the pea protein isolate was being tested. A similar trend in mixing characteristics was observed with a mixture of specialty wheat protein and pea protein isolate **(Fig. 10)**. These curves appear smoother with less wild swings compared to protein blends shown in **Fig. 9**. Such interesting functional properties of a wheat/pea protein blend are in addition to the enhanced nutritional

Figure 9. *Mixing curves* of wheat protein/pea protein isolate mixtures.*



***Sample** : **Wheat Starch** : **Water** ratio for mixograph test is 5:5:6.7

Figure 10. *Mixing curves* of specialty wheat protein/pea protein isolate mixtures.*



***Sample** : **Wheat Starch** : **Water** ratio for mixograph test is 5:5:6.7

Table 5. *Mixing characteristics of wheat protein/pulse protein blends and specialty wheat protein/pulse protein blends.*

Blend	Mixing Time, min.	Mixing Resistance at the Peak, M.U.	Mixing Resistance after 10 min., M.U.
Wheat Protein/Pea Protein Isolate	1.0*	7.8*	5.8*
Wheat Protein/Lentil Protein	0.5	9.0	6.8
Wheat Protein/Faba Bean Protein	0.8	8.0	6.7
Wheat Protein/Pea Protein Concentrate	1.5	7.2	6.0
Specialty Wheat Protein/Pea Protein Isolate	0.9*	7.5*	6.3*
Specialty Wheat Protein/Lentil Protein	1.0	6.2	6.2
Specialty Wheat Protein/Faba Bean Protein	0.8	6.5	5.5
Specialty Wheat Protein/Pea Protein Concentrate	1.0	6.5	5.6

*Average data from four sources of pea protein isolates

WHEAT PROTEIN/PULSE PROTEIN BLENDS ▶ Continued

value resulting from improved amino acid composition of the blend.

Four pulse proteins were each blended with wheat protein or specialty wheat protein to determine their effects on dough mixing characteristics using a mixograph **(Table 5)**. In general, pea protein isolates in admixture with wheat protein or specialty wheat protein generated a strong, stable mixing curve. A rapid rise to reach the peak was observed among the samples with the wheat protein/lentil protein blend exhibiting the fastest rise and also the highest mixing resistance at the peak.

Due to its lower protein content, the blend of pea protein concentrate exhibited a weaker mixing curve compared to that of pea protein isolate as indexed by mixing resistance at the peak. Faba bean protein has a strong mixing resistance at the peak when blended with wheat protein than when it is blended with specialty wheat protein. The most stable mixing curve was displayed by a blend of specialty wheat protein and lentil protein exhibiting no change in mixing resistance from the peak to the end of mixing after 10 min.

FUNCTIONALITY IN DOUGH SYSTEMS

Protein quality is one of the most important characteristics of a flour, which in turn depends on protein quantity and composition. Protein quality, for example, in a flour used in a yeast-leavened product is responsible for the formation of the crumb's framework structure. When the term "protein quality" is used in conjunction with bakery flour, it actually means "gluten quality." Strong gluten-quality is normally associated with hard wheat flours used in bread and roll production, whereas weak gluten quality is displayed by soft wheat flours used in cakes and pastries. Flour or protein quality is best defined in terms of its intended end-use and the bake test remains the "gold standard" for determining flour quality, or the effect of an additive.

The science of rheology studies the deformation and flow of matter in response to an applied stress. A viscoelastic dough exhibits shear-thinning and thixotropic behavior, which is a consequence of its complex structure wherein starch granules are surrounded by a three-dimensional protein network. Wheat gluten is the viscoelastic protein responsible for dough structure formation.

Protein quality of a wheat flour and the influence of additives on dough behavior are oftentimes estimated using rheological instruments. Examples of these instruments are the mixograph, farinograph, extensograph, alveograph, and texture analyzer, which are commonly used in flour and dough testing laboratories of many universities and bakeries. They measure mixing time (peak time), resistance to mixing (dough strength), tolerance to over mixing, water absorption, stability, mixing tolerance index, resistance to extension, extensibility, and deformation energy.

MIXOGRAPH

The mixograph is an instrument that measures and records the resistance of a dough to mixing. The mixing curve indicates optimum water absorption of a flour to produce a bread dough, optimum development or mixing time of the dough, and resistance to mixing, an indicator of dough strength. The mixograph is often used on a mixture of flour and water, but it has been used to study the effects of added ingredients on dough mixing properties. A typical mixing curve called a mixogram is depicted in **Fig. 11 (Appendix B)** for a bread flour sample.

The addition of 1%, 3%, and 5% Arise® 5000 to wheat flour progressively decreased dough mixing time as illustrated in **Fig. 12**. Arise® 6000 exhibited the same mixing time reduction **(Fig. 13, Appendix B)**, whereas vital wheat gluten gave no reduction in dough mixing time **(Fig. 14, Appendix B)**. Arise® 5500 with heavier bulk density than Arise® 5000 displayed a similar trend in reduction in mixing time, but the reducing effect is less pronounced **(Fig. 15, Appendix B)**

Resistance to mixing appears to be unaffected by the addition of Arise® 8000 to wheat flour. However, it tends to increase mixing time by 0.5-1.0 min especially at higher levels of incorporation (3-5%) **(Fig. 16)**. L-cysteine-treated Arise® 8100 decreased mixing time by 1-2 minutes at higher levels of incorporation (3-5%) with insignificant effect on resistance to mixing **(Fig. 17)**. A smaller decrease in mixing time (1.0-1.5 min) was observed when Arise® 8200, also L-cysteine treated, was added at 1-5% level (**Fig. 18**).

Arise® 5000 and Arise® 5500, with similar properties except for the heavier particle-density of the latter, were added to wheat flour at 1.0-2.0% level to test their effect on mixing time **(Table 6)**. Both Arise® wheat protein isolates reduced mixing time by 1.0-1.5 minutes compared to the control wheat flour with no added wheat protein isolate.

The mixograph results presented in **Table 7 (Appendix A)** were from a published university study that used three wheat flour samples: a pastry flour (unbleached flour), a tortilla flour (bleached, enriched, and malted flour), and a bread flour (bleached bakers-enriched flour containing malted barley flour, niacin, iron, thiamin mononitrate, riboflavin, and folic acid). Compared to just flour itself, the addition of 3% Arise® 5000 or Arise® 6000 consistently decreased mixing time, whereas 3% vital wheat gluten increased mixing time for the bread flour but decreased mixing time for the pastry and tortilla flours. All three protein additives increased the resistance to mixing (height of the mixing curve) of the pastry and tortilla flours, but the effect on bread flour was generally inconsistent.

Figure 12. *Effect on mixograph curve of wheat flour after adding 1%, 3% or 5% of Arise 8000.*

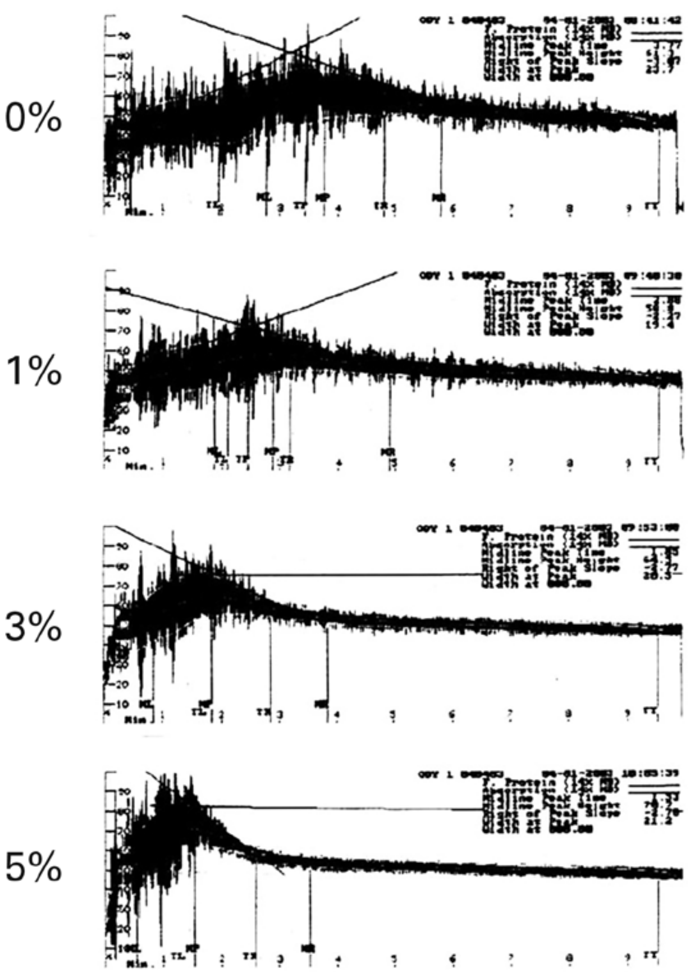
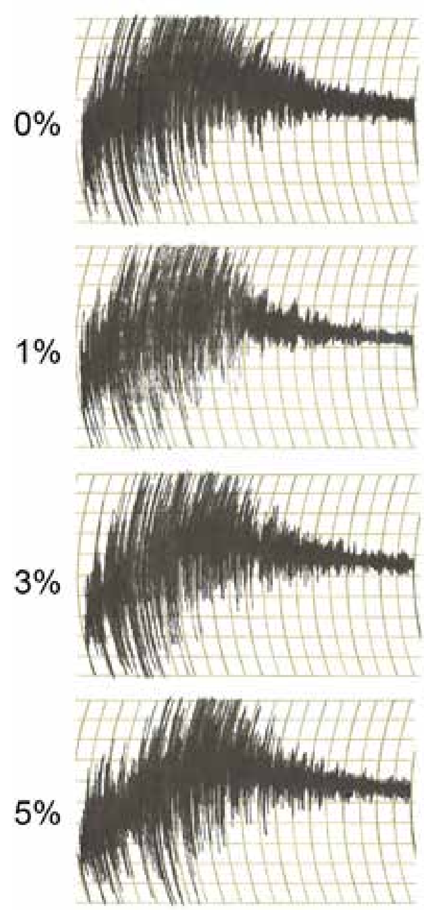


Figure 16. *Effect on mixograph curve of wheat flour after adding 1%, 3% or 5% of Arise 8000.*



FUNCTIONALITY IN DOUGH SYSTEMS ▶ Continued

Figure 17. *Effect on mixograph curve of wheat flour after incorporating 1%, 3% or 5% of Arise® 8100.*

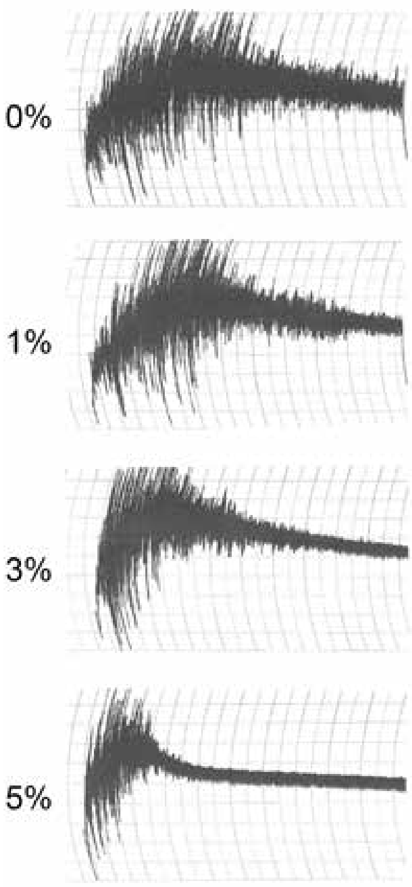
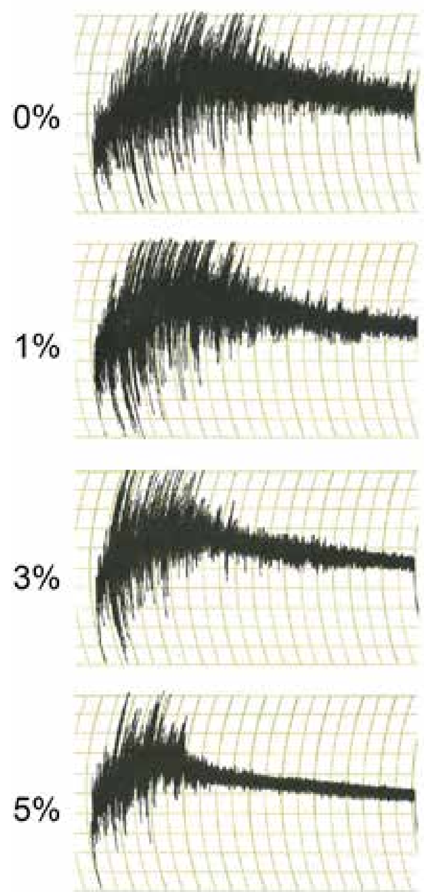


Figure 18. *Effect on mixograph curve of wheat flour after incorporating 1%, 3% or 5% of Arise® 8200.*



Key Points of Arise® 8000:

- Clean label (no added processing aids)
- Highly concentrated source of protein, averaging ~94% (d.b.)
- High viscoelasticity when hydrated
- Strengthens dough
- Increases resistance to mixing
- Increases resistance to dough extension
- Non-GMO Project Verified

Table 6. *Effect on mixing time of adding 1.0%, 1.5% or 2.0% of Arise® 5000 or Arise® 5500 in wheat flour.*

Protein Source	Mixing Time, min.
Control Wheat Flour (No Additive)	4.5
Arise® 5000	
1.0%	3.2
1.5%	3.5
2.0%	3.0
Arise® 5000	
1.0%	3.2
1.5%	3.2
2.0%	3.2

FARINOGRAPH

A farinograph measures and records the mechanical resistance of a dough during mixing and kneading. The parameters measured in a farinograph curve (farinogram) are the following: Water Absorption (ml) – the amount of water necessary to center the farinograph curve on the 500 B.U. line; Dough Development Time or Mixing Time (min) – time duration to the nearest half minute initiated by the addition of water to a flour and terminated by the development of the maximum consistency of a dough; Mixing Tolerance Index or MTI (B.U.) – the difference in B.U. from the top of the curve at the peak to the top of the curve measured 5 min after the peak is reached; Stability (min) – difference in time to the nearest half minute between the time where the top of the curve first intercepts the 500 B.U. line and the time where the curve leaves the 500 B.U. line. Farinograph Stability indicates the tolerance of the dough to mixing. MTI also relates to tolerance to mixing and can be related to Stability. A dough with a good tolerance to mixing will have a high Stability value in minutes, but a low MTI value in BU units. A typical farinogram for wheat flour is illustrated in **Fig. 19 (Appendix B)**.

Four different production samples of Arise® 5000 at a 1.5% level of addition were compared for their effects on farinograph parameters of a wheat flour. The data presented in **Table 8 (Appendix A**) shows that Arise® 5000 has the general effects of increasing dough absorption, decreasing dough development time (i.e. mixing time), increasing the value reported for Mixing Tolerance Index (MTI), and decreasing the Stability value.

At the same level of incorporation (1.0-2.0%) in wheat flour, Arise® 5000 and Arise® 5500 exhibited a shorter mixing time accompanied by lower Stability and increased MTI when compared to control wheat flour with no added Arise® wheat protein isolate **(Table 9)**.

Farinograph curves were run on wheat flour with 1.0%, 1.5% and 2.0% of Arise® 5000 or Arise® 6000 added to the flour. The results indicated that as the level of addition increased, dough absorption increased **(Table 10)**, while farinograph Stability value decreased and MTI value increased with the addition of either of those two Arise® ingredients. While the peak time tended to decrease with the addition of either Arise® 5000 or Arise® 6000, the decrease was not directly correlated to the level of Arise® added. These farinograph results are indicative generally of a reducing action on dough protein.

The dough properties of another wheat flour with 1.0-2.0% added Arise® wheat protein isolate or wheat gluten were examined using the mixograph and farinograph instruments **(Table 11)**. Mixing time (peak time) in both instruments was reduced by Arise® 5000, Arise® 5500 and Arise® 6000 compared to the control flour. Farinograph Stability value was generally decreased while water absorption and MTI were generally increased by addition of the three previously-mentioned wheat protein isolates. Wheat gluten and Arise® 8000 tended to have comparable mixograph and farinograph mixing properties at 1.0-2.0% incorporation level. Compared to the control flour, both of those protein products produced higher farinograph water absorption and Stability values, but tended to have a decreased MTI value.

Table 9. *Impact of adding 1.0%, 1.5% or 2.0% of Arise® 5000 or Arise® 5500 on farinograph quality of wheat flour.*

Protein Source	Peak Time, min.	Stability, min.	Mixing Tolerance Index, B.U.
Control Wheat Flour (No Additive)	5.9	13.0	29
Arise® 5000			
1.0%	4.8	9.2	39
1.5%	5.3	10.1	35
2.0%	4.8	9.6	34
Arise® 5500			
1.0%	5.0	9.2	34
1.5%	4.6	8.0	36
2.0%	4.4	6.2	46

FUNCTIONALITY IN DOUGH SYSTEMS ▶ Continued

FARINOGRAPH ▶ Continued

Table 10. *Effects of level of addition of Arise® 5000 or Arise® 6000 on farinograph quality of wheat flour.*

Ingredients	Absorption, %	Peak Time, min.	Stability, min.	MTI, B.U.[a]
Control	61.0	6.5	14.75	30
1.0% Arise® 5000	63.0	5.5	10.00	40
1.5% Arise® 5000	64.0	5.0	8.50	50
2.0% Arise® 5000	65.0	5.5	6.75	55
1.0% Arise® 6000	63.0	5.5	10.00	35
1.5% Arise® 6000	64.0	6.5	7.75	50
2.0% Arise® 6000	64.5	6.0	7.25	60

[a]**MTI, B.U.** = Mixing Tolerance Index, Brabender Units

Table 11. Comparison of mixograph and farinograph quality of wheat flour at different levels of addition of wheat gluten or Arise® wheat protein isolates.

		Mixograph	Farinograph			
Protein Source	**Level**	**Peak Time min.**	**Water Abs. %**	**Peak Time min.**	**Stability min.**	**MTI* BU**
Control Wheat Flour (No Additive)	0	4.50	57.3	5.9	13.0	29
Wheat Gluten	1.0	4.25	58.4	5.0	17.3	30
	1.5	4.00	58.5	5.3	14.9	19
	2.0	5.00	59.8	7.4	24.4	15
Arise® 5000	1.0	3.20	58.9	4.8	9.2	39
	1.5	3.50	59.6	5.3	10.1	35
	2.0	3.00	59.6	4.8	9.6	34
Arise® 5500	1.0	3.10	59.7	5.0	9.2	34
	1.5	3.10	58.1	4.6	8.0	36
	2.0	3.20	60.3	4.4	6.2	46
Arise® 6000	1.0	3.50	58.2	5.2	10.1	44
	1.5	3.50	59.0	4.7	10.4	38
	2.0	3.00	59.9	6.0	23.5	15
Arise® 8000	1.0	4.00	58.2	5.0	13.5	20
	1.5	4.00	58.3	7.0	16.1	15
	2.0	4.00	59.9	7.7	26.4	16

***MTI** = Mixing Tolerance Index

EXTENSOGRAPH

The extensograph provides information about dough resistance to stretching and extensibility by measuring the force to pull a hook through a cylindrically-shaped piece of dough until it breaks. Extensibility is reported as the length or distance (in mm) of stretching of the dough piece at the time of rupture, whereas resistance to extension is measured by the stretching force and is recorded by the height of the extensograph curve.

The appearance of a force-time curve (extensogram) is seen on a wheat flour dough in **Fig. 20 (Appendix B)**. Compared to the control flour dough (no additive) with an extensibility of 144 mm after a 45-minute rest period, the extensibility of the dough containing 0.5% or 1.0% Arise® 5000 increased to 155-173 mm **(Table 12)**. Compared to the data at a 45-minute rest period, extensibility tended to decrease after 90 minutes (97-101 mm) then appeared to level off after a rest period of 135 minutes (95-102 mm).

It took a higher percentage addition (up to 1.0-1.5%) for Arise® 6000 to elicit the same increase (153-178 mm) in extensibility at 45 minutes as Arise® 5000. The dough at a 90-minute rest period had lesser extensibility (111 mm) compared to 45 minutes, and both levels of Arise® 6000 exhibited similar extensibility values. At a 135-minute rest period, the addition of 1.0% Arise® 6000 showed comparable extensibility to the control (81 mm vs 83 mm). However, the dough with 1.5% Arise® 6000 at 135 minutes gave a more extensible dough (extensibility of 94 mm). Overall, the general trend of the data in **Table 12** indicates a larger effect on extensibility by Arise® 5000 compared to Arise® 6000. In contrast to the above observations on extensibility, the resistance to extension of the dough tended to decrease with the addition of 0.5% to 1.0% Arise® 5000 or 1.0% to 1.5% Arise® 6000.

In a separate experiment, Arise® 6000 was tested in the extensograph at 1%, 2% and 3% levels in a wheat

FUNCTIONALITY IN DOUGH SYSTEMS ▸ Continued

***Table 12.** Extensibility and resistance to extension at three resting periods of wheat flour with varying levels (0.5-1.5%) of Arise® 5000 or Arise® 6000 as determined in an extensograph.*

		45 min.		90 min.		135 min.	
Protein Source	**Level %**	**Res***	**Ext***	**Res***	**Ext***	**Res***	**Ext***
Control Wheat Flour (No Additive)	0	625	144	770	93	880	81
Arise® 5000	0.5	625	155	830	97	780	95
	1.0	560	173	745	101	700	102
Arise® 6000	1.0	590	153	780	111	760	83
	1.5	580	178	770	111	810	94

*__Res__ = Resistance to Extension (EU); **Ext** = Extensibility (mm)

flour. The results show the general trend previously observed on the increase in dough extensibility **(Table 13, Appendix A)**, but a decrease in resistance to dough extension.

Another extensograph study was a comparison of 1%, 3% or 5% added wheat gluten, Arise® 5000, Arise® 5500 or Arise® 8000 to wheat flour. Consistent with earlier results, Arise® 5000 exhibited a reduction in resistance to extension at the three rest periods, which appeared to be proportional to the level added (1-5%) at 45-min rest period, but not with the other two rest periods **(Table 14)**. The increase in extensibility tended to be proportional to the level of Arise® 5000 at the 45-min rest period, but not at the 90- and 135-min rest periods. By contrast, Arise® 5500 demonstrated a reduction in resistance to extension that is proportional to the level of added Arise® 5500 at all three rest periods. The increased extensibility tended to be unaffected by the level of added Arise® 5500 at any of the three rest periods. Wheat gluten displayed an increased resistance to extension that is proportional to the level of added wheat gluten at the three rest periods; however, there is no clear trend of its effect on extensibility. At the 90- and 135-min rest periods but not at the 45-min rest period, the increase in resistance to extension of Arise® 8000 tended to be proportional to the level of added Arise® 8000. The results on extensibility as affected by added Arise® 8000 are inconsistent tending to be diminished at a higher level of addition (3-5%).

Extensograph characteristics of wheat gluten and four wheat protein isolates as flour additives at 1.0%, 1.5% or

***Table 14.** Extensibility and resistance to extension at three resting periods of wheat flour with varying levels (1.0-5.0%) of vital wheat gluten or Arise® wheat protein isolates as determined in an extensograph.*

		45 min.		90 min.		135 min.	
Protein Source	**Level %**	**Res***	**Ext***	**Res***	**Ext***	**Res***	**Ext***
Control Wheat Flour (No Additive)	0	625	144	770	93	880	81
Wheat Gluten	1.0	695	166	775	139	765	117
	3.0	780	141	>1000	103	960	81
	5.0	860	142	1060	89	990	77
Arise® 5000	1.0	580	162	680	162	620	130
	3.0	470	172	700	140	650	126
	5.0	440	203	530	152	495	136
Arise® 5500	1.0	610	169	880	117	860	99
	3.0	520	161	590	137	610	113
	5.0	450	144	440	134	450	113
Arise® 8000	1.0	810	134	1000	105	930	88
	3.0	765	137	1015	90	970	82
	5.0	775	133	1030	87	1040	81

*__Res__ = Resistance to Extension (EU); **Ext** = Extensibility (mm)

EXTENSOGRAPH ▶ Continued

2.0% were measured using a different protocol of rest periods: 30, 60 or 90 min. At the 30-min rest period, Arise® 5000, Arise® 5500, and Arise® 6000 showed a decrease in resistance-to-extension and an increase in extensibility, but those changes do not appear to be proportional to the level of added Arise® wheat protein isolate **(Table 15)**. The same general trend in increased extensibility and decreased resistance-to-extension was observed after the 60-min and 90-min rest periods. Wheat gluten and Arise® 8000 behaved differently with no clear general trend on resistance-to-extension, but extensibility tended to generally increase over the three rest periods.

ALVEOGRAPH

In an alveograph, a sheet of dough of defined thickness is expanded by air pressure into a bubble until it is ruptured, and the resistance to extension (deformation) and the extent to which it can be stretched is measured. The internal pressure in the bubble is graphically recorded. The parameters measured in an alveogram are P (measure of dough tenacity; resistance to extension/deformation; maximum pressure reached blowing the dough piece to rupture), L (measure of dough extensibility; maximum volume of air that the bubble is able to contain), W (measure of deformation energy; area under the curve; energy needed to make the bubble as big as it could go before it burst) and P/L ratio (a measure of how high or how low the pressure is that developed during the test). The alveograph curve for wheat flour is graphically recorded as shown in **Fig. 21 (see Appendix B)**.

When evaluated using an alveograph, Arise® 5000 has a larger effect on increasing dough extensibility (L) compared to Arise® 6000 **(Table 16)**. For example, 0.5% Arise® 5000 tended to cause higher extensibility than the addition of 1.0% to 1.5% Arise® 6000. In a separate experiment, high levels of 3% and 5% of Arise® 5000 were evaluated for their effects on alveograph parameters. **Table 17 (Appendix A)** shows that dough extensibility (L) generally increased and resistance to extension (P)

Table 15. *Extensibility and resistance to extension at three resting periods of wheat flour with varying levels (1.0-2.0%) of vital wheat gluten or Arise® wheat protein isolates as determined in an extensograph.*

		30 min.		60 min.		90 min.	
Protein Source	**Level %**	**Res***	**Ext***	**Res***	**Ext***	**Res***	**Ext***
Control Wheat Flour (No Additive)	0	406	154	612	144	720	142
Wheat Gluten	1.0	314	198	490	184	591	164
	1.5	422	180	616	150	690	143
	2.0	326	197	610	170	647	155
Arise® 5000	1.0	290	189	452	153	492	152
	1.5	279	203	434	175	475	170
	2.0	292	188	480	163	497	154
Arise® 5500	1.0	262	193	474	166	499	161
	1.5	316	193	484	160	538	158
	2.0	295	186	482	169	526	162
Arise® 6000	1.0	350	190	556	161	548	170
	1.5	286	200	428	173	472	170
	2.0	286	198	433	177	476	169
Arise® 8000	1.0	338	174	594	173	623	163
	1.5	377	194	628	164	640	142
	2.0	370	199	576	168	729	141

***Res** = Resistance to Extension (EU); **Ext** = Extensibility (mm)

FUNCTIONALITY IN DOUGH SYSTEMS ▶ Continued

ALVEOGRAPH ▶ Continued

decreased, respectively, as the level of protein additive rose. By comparison, Arise® 5500 added to wheat flour at 1-5% level tended to have higher extensibility and lower resistance to extension when matched against the control **(Table 18, Appendix A)**.

With respect to Arise® 8000, the resistance to dough extension (P) was increased compared to the control (no additive), and the increase was apparently directly related to the level of Arise® 8000 **(Table 19)**. Dough extensibility (L) tended to decrease with the incorporation of Arise® 8000.

Resistance to extension (P) of dough tended to increase for both wheat gluten and Arise® 8000 compared to the control **(Table 20)**. By contrast, Arise® 5000 (1.5-2.0%) and Arise® 6000 (1.0-2.0%) tended to have reduced resistance to extension. Dough extensibility tended to increase for Arise® 5000 (2.0%), Arise® 5500 (1.5-2.0%) and Arise® 6000 (1.5-2.0%). In general, the P/L ratio tended to decrease with the addition of Arise® 5000, Arise® 5500 and Arise® 6000, but generally increased with wheat gluten and Arise® 8000 compared to the control. The W value, a measure of deformation energy or dough strength, tended to decrease with Arise® 5000 and Arise® 6000, but generally increased with wheat gluten.

In another alveograph measurement, Arise® 5000 or Arise® 5500 added at 1.0%, 3.0% or 5.0% in wheat flour exhibited a general trend of decreased resistance-to-extension and increased extensibility **(Table 21)**. The deformation energy (W) also tended to decrease. Conversely, wheat gluten and Arise® 8000 increased the resistance-to-extension (P) and tended to have decreased extensibility (L) with Arise® 8000. However, wheat gluten tended to increase extensibility at 1.0-3.0% but tended to decrease it at a level of 5.0%. Deformation energy (W) generally increased with the addition of wheat gluten and Arise® 8000.

Table 16. *Alveograph data of wheat flour with varying levels (0.5-1.5%) of Arise® 5000 or Arise® 6000.*

Additive	Extensibility, mm	Resistance to Extension, mm
No additive	79	121
0.5% Arise® 5000	90	116
1.0% Arise® 5000	97	114
1.0% Arise® 6000	88	117
1.5% Arise® 6000	87	119

Table 19. *Alveograph data of wheat flour containing 1%, 3% or 5% of Arise® 8000.*

Additive	Extensibility, mm	Resistance to Extension, mm
No additive	79	121
1% Arise® 8000	68	129
3% Arise® 8000	76	142
5% Arise® 8000	79	167

__Table 20.__ Alveograph data of wheat flour with varying levels (1.0-2.0%) of wheat gluten or Arise® wheat protein isolates.

Protein Source	Level %	P* (mm H_2O)	L* (mm)	W* (10^{-4} J)	P/L*
Control Wheat Flour (No Additive)	0	79	87	249	0.91
Wheat Gluten	1.0	88	78	261	1.13
	1.5	95	84	296	1.13
	2.0	89	90	296	0.99
Arise® 5000	1.0	80	75	216	1.07
	1.5	76	86	224	0.88
	2.0	74	95	235	0.78
Arise® 5500	1.0	86	87	257	1.02
	1.5	81	97	254	0.84
	2.0	80	95	242	0.84
Arise® 6000	1.0	78	86	232	0.91
	1.5	73	124	261	0.59
	2.0	75	107	244	0.70
Arise® 8000	1.0	87	69	236	1.26
	1.5	92	69	247	1.33
	2.0	91	88	297	1.03

***P** = Dough tenacity or resistance to extension; **L** = Extensibility; **W** = Deformation energy; **P/L** = Ratio of resistance to extension to extensibility

__Table 21.__ Alveograph data of wheat flour with varying levels (1.0-5.0%) of wheat gluten or Arise® wheat protein isolates.

Protein Source	Level %	P* (mm H_2O)	L* (mm)	W* (10^{-4} J)
Control Wheat Flour (No Additive)	0	121	79	349
Wheat Gluten	1.0	124	93	420
	3.0	134	87	445
	5.0	152	75	464
Arise® 5000	1.0	112	93	351
	3.0	92	121	300
	5.0	87	115	253
Arise® 5500	1.0	114	84	335
	3.0	116	80	325
	5.0	126	74	338
Arise® 8000	1.0	129	68	345
	3.0	142	76	427
	5.0	167	79	540

***P** = Dough tenacity or resistance to extension; **L** = Extensibility; **W** = Deformation energy

FUNCTIONALITY IN DOUGH SYSTEMS ▸ Continued

KIEFFER EXTENSIBILITY TEST

Dough strength and extensibility can be measured using the TA.XTPlus Texture Analyzer fitted with the SMS/Kieffer Rig (Stable Micro Systems/Texture Technologies). For example, wheat flour (10 g, 14% mb), 0.2 g sodium chloride and water were mixed in the mixograph to optimum development at optimum water level for each treatment. After mixing, a dough was gently formed by hand into a crude rectangle and placed on the grooved base in the Teflon former which had been generously coated with mineral oil and lined with Teflon strips. The cover was placed on top of the dough and the loaded former was placed in the clamp and tightened. Excess dough that extruded from the edges of the former was cut off and discarded. After 30 min, the clamp was removed and the top of the former was pulled back to reveal a single dough strip. Only full strips were tested. The dough strip was gently lifted, avoiding stretching, from the former using the Teflon strip and the dough strip was placed on the grooved region of the sample plate. The sample plate was placed in the testing rig with the probe hook positioned beneath the strip. The dough strip was pulled upward by the hook until it ruptured. Maximum force (g-force) and distance to rupture (mm) were taken as resistance to extension and dough extensibility, respectively **(Fig. 22, Appendix B)**.

By employing the Kieffer extensibility test, the maximum force as a measure of resistance to extension was reduced with Arise® 5000 at 1.0-2.0% level while the dough extensibility (distance) was increased **(Table 22)**. Arise® 5500 behaved somewhat differently with the resistance to extension being decreased only at the 2.0% level whereas extensibility was increased only at the 2.0% level.

As expected, wheat gluten and Arise® 8000 demonstrated an increase in resistance to extension when added to wheat flour at the 1.0-2.0% level **(Table 23)**. Arise® 8000, but not wheat gluten, showed reduced extensibility at those 3 levels of incorporation. A decreased in resistance to extension was exhibited by both Arise® 5000 and Arise® 6000 at 1.0-2.0%, but Arise® 5500 showed the same property only at the 2.0% level. Both Arise® 5000 and Arise® 6000 displayed increased extensibility at 1.0-2.0%, but Arise® 5500 demonstrated increased extensibility only at the 2.0% level.

Table 22 *Kieffer extensibility test comparing Arise® 5000 with Arise® 5500 at three levels (1.0-2.0%) of addition in wheat flour.*

Protein Source	Force, g	Distance, mm
Control Wheat Flour (No Additive)	31.8	32.2
Arise® 5000		
1.0%	30.2	35.8
1.5%	27.1	35.5
2.0%	26.4	41.3
Arise® 5500		
1.0%	33.8	25.6
1.5%	33.1	26.8
2.0%	28.5	41.8

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Table 23. *Kieffer extensibility test comparing wheat gluten and four Arise® wheat protein isolates at three levels (1.0-2.0%) of addition in wheat flour.*

Protein Source	Level, %	Force, g	Distance, mm
Control Wheat Flour (No Additive)	0	31.8	32.2
Wheat Gluten	1.0	34.0	37.0
	1.5	34.0	30.6
	2.0	34.2	38.8
Arise® 5000	1.0	30.2	35.8
	1.5	27.1	35.5
	2.0	26.4	41.3
Arise® 5500	1.0	33.8	25.6
	1.5	32.6	26.8
	2.0	28.5	41.8
Arise® 6000	1.0	26.3	37.3
	1.5	23.5	60.4
	2.0	23.8	57.3
Arise® 8000	1.0	39.8	28.7
	1.5	33.0	30.6
	2.0	33.3	29.7

WHITE PAN BREADS

The performance of Arise® 5000 and Arise® 6000 in white pan bread made using a sponge and dough process was evaluated at the American Institute of Baking (AIB) International using 1.0%, 1.5%, or 2.0% levels of addition based on flour **(Table 24, Appendix A)**. As the level of addition increased from 1.0% to 2.0%, water absorption increased from 61% for the control (no additive) to 63.0-65% for Arise® 5000 and from 61% for the control (no additive) to 63.0-64.5% for Arise® 6000 **(Table 25)**. The data also showed the specific volume of control

Table 25. *Properties of sponge and dough white pan breads formulated with varying levels (1.0-2.0%) of Arise® 5000 or Arise® 6000*

Ingredients	Absorption, %	Specific Volume, cc/g	CrumbScan™ Fineness	Total Quality Score
Control	61.0	5.28	929	81.63
1.0% Arise® 5000	63.0	5.31	934	82.38
1.5% Arise® 5000	64.0	5.54	933	82.88
2.0% Arise® 5000	65.0	5.45	913	83.25
1.0% Arise® 6000	63.0	5.60	930	83.00
1.5% Arise® 6000	64.0	5.54	916	82.13
2.0% Arise® 6000	64.5	5.56	940	81.88

Source: AIB study

WHITE PAN BREADS ▶ Continued

bread was 5.28 cc/g, which was improved by the addition of Arise® 5000 (5.31-5.54 cc/g), although the effect was not directly related to the level of addition. Arise® 6000 displayed a similar trend as Arise® 5000 except that the specific volume of the former is slightly higher (5.54-5.60 cc/g). Two parameters, crumb fineness and total quality score, were improved by the addition of both Arise® products, but again, the trend was not proportional to the level of addition.

In a white pan bread formula, addition of 1.5% Arise® 8100 improves loaf volume (950 cc) compared to control bread (865 cc). When used at 0.5% level to replace emulsifiers in bread, Arise® 8100 yields comparable bread volume (855 cc) as the breads with 0.5% DATEM (865 cc) or SSL (830 cc).

Bread products re-heated in a microwave oven become soft immediately after heating, but develop a tough, rubbery or leathery texture upon cooling. It is believed that the toughness observed might be caused by the interaction of adjacent gluten strands when the water was removed during microwave heating. The effect of added protein ingredients on the microwave-induced toughness of pup loaf bread re-heated in a microwave oven is documented in a published study from Kansas State University. The addition of vital wheat gluten at 1%, 2% and 3% did not significantly affect microwave-induced toughness compared to the control. The addition of 1% Arise® 5000 did not significantly affect toughness after microwaving, but the addition of 2% and 3% Arise® 5000 were effective in reducing microwave-induced toughness.

WHOLE GRAIN BREADS

To evaluate the benefits of Arise® 6000 in whole grain products, whole wheat breads containing 6% vital wheat gluten were baked together with an additional 1% vital wheat gluten or 1% Arise® 6000 while all other ingredients remained the same (**Table 26, Appendix A**). When compared against the control whole wheat bread, the 1% Arise® 6000 decreased both dough mixing time (7.1%) and proof time (7.6%) whereas the 1% vital wheat gluten increased both parameters by 14.3% and 3.4%, respectively. (**Figs. 23 and 24**). Either of the 1% added protein ingredients produced bread with an increased loaf volume (5.1%) compared to the control bread.

Figure 23. *Effect of addition of 1% Arise® 6000 or 1% vital wheat gluten on dough mixing time of a whole wheat bread formula.*

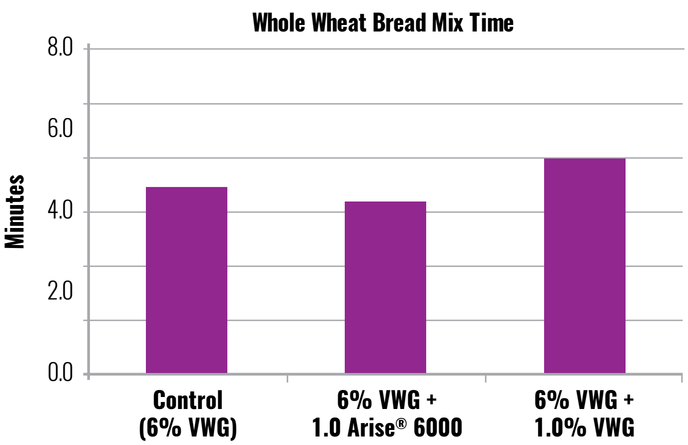
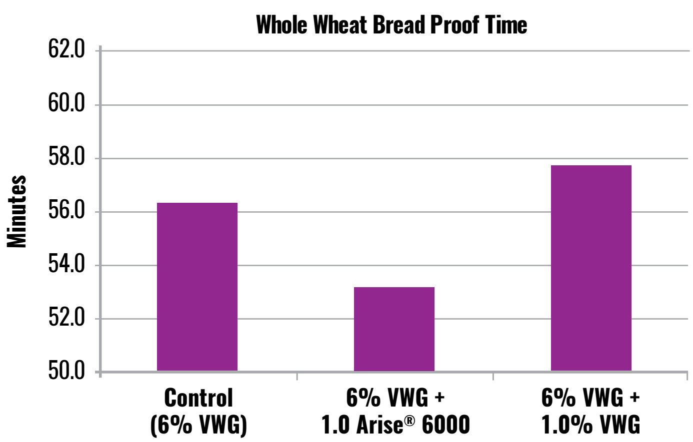


Figure 24. *Effect of addition of 1% Arise® 6000 or 1% vital wheat gluten on proof time of a whole wheat bread formula.*



HIGH-PROTEIN, HIGH-FIBER BREADS

In a study conducted at AIB International, a protein- and fiber-enriched whole wheat (red or white) bread was formulated by incorporating high-protein (Arise® 5000 plus vital wheat gluten) and high-fiber (Fibersym® RW plus soy fiber) ingredients **(Table 27, Appendix A)**. As shown in **Table 28**, the high-protein, high-fiber (HPHF) doughs had higher absorptions and required considerably less high-speed mixing time (3-5 minutes shorter) than the control doughs. The higher absorptions were primarily due to higher protein content, and the shorter mixing times were attributed to Arise® 5000 wheat protein isolate. Dough consistency out of the mixer was generally good for all samples, trending to slightly sticky and elastic for the HPHF doughs. The same doughs improved over the course of the 30-minute floor time, to the point that most were judged good at the makeup stage. Proof times were very quick for the HPHF doughs, about 17-20 minutes shorter than the control doughs. Bake times were increased from 20 minutes normally used for the control doughs to 24 minutes for the HPHF doughs in an effort to bake out the greater amount of moisture and reduce the tendency of the breads to shrink on cooling. HPHF breads exhibited significantly greater volume (260-325 cc higher) than the corresponding control breads. Total quality bread scores showed no remarkable differences in quality between variables **(Table 28)**. The properties of HPHF whole red wheat breads were comparable to those of HPHF whole white wheat breads. Crust and crumb color were lighter for the breads made with whole white wheat flour, in keeping with its nature. Internal bread crumb structures measured by CrumbScan™ are also presented in **Table 28**. Higher values for Composite Fineness and Composite Elongation indicate better quality. The two HPHF breads exhibited a softer crumb (i.e., prolonged shelf-life) compared to the corresponding control breads over 10 days of storage **(Figs. 25 and 26)**.

The HPHF bread formula in the above AIB study **(Table 27, Appendix A)** was revised to convert it to a high-protein, low net carbohydrate bread formula **(Table 29, Appendix A)**. In this flour-less bread formula, an analog or composite flour was developed consisting of a blend of Fibersym® RW resistant wheat starch, Arise® 8000, Arise® 5000 and oat fiber. Arise® 8000 is the major protein source to provide the strength (elasticity) in the dough. To provide extensibility properties, Arise® 5000 was added to improve dough handling and machinability. A precise balance between the above two Arise® proteins is necessary to produce a good quality baked product. The Nutrition Facts was generated using Genesis R&D software program showing 3 grams of net carbohydrates and 12 grams of protein per serving size of 75 grams **(Fig. 27)**. If calculated using a serving size of 28 grams, the amount of net carbohydrates is 1 gram and that of the protein is 5 grams.

Figure 25. *Change in crumb firmness during 10-day storage of high-protein, high-fiber bread from whole red wheat flour with added Arise® 5000.*

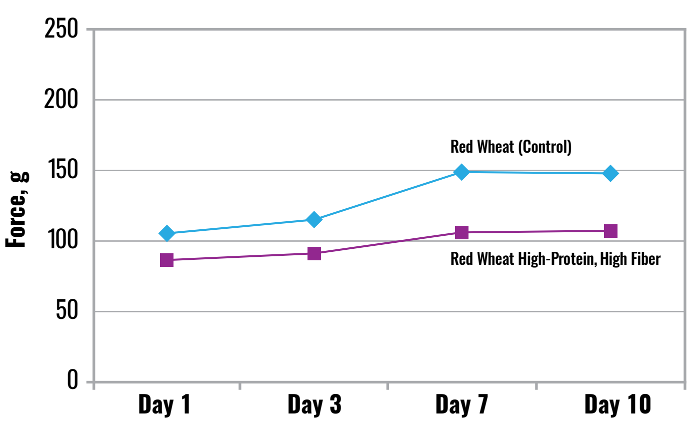
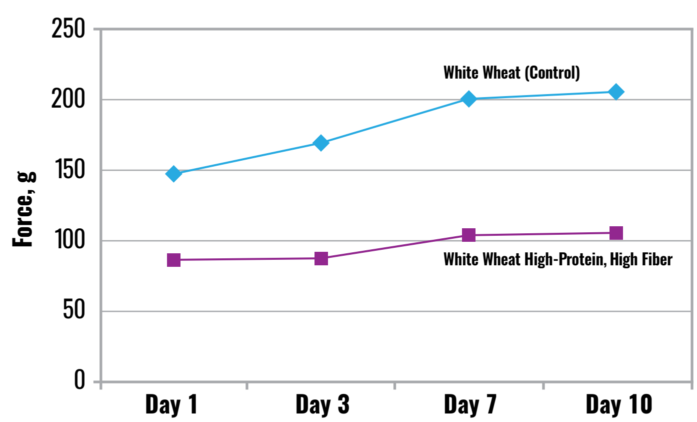


Figure 26. *Change in crumb firmness during 10-day storage of high-protein, high-fiber bread from whole white wheat flour with added Arise® 5000.*



HIGH-PROTEIN, HIGH-FIBER BREADS ▶ Continued

Table 28. *Dough and bread characteristics of control and high-protein, high-fiber formulas.*

Property	Whole Red Wheat Flour		Whole White Wheat Flour	
	Control	HPHF*	Control	HPHF*
Absorption, %	69.7	78.0	75.7	80.0
Mixing time, min	8.5	5.0	8.0	5.0
Proof time, min	53	36	52	34
Bread volume, cc	2200	2460	2144	2416
Specific vol., cc/g	4.63	5.32	4.52	5.21
Quality				
Dough score	22.0	24.5	19.2	22.8
External score	15.0	13.0	14.2	13.2
Internal score	49.5	43.2	46.8	42.5
Total score	86.5	80.7	80.2	78.5
CrumbScan™ Data				
Composite Fineness	853	777	891	737
Composite Elongation	1.39	1.41	1.41	1.35

***HPHF** = High-Protein, High-Fiber

FLOUR TORTILLAS

A good-quality flour tortilla should be light in color, opaque, well puffed, soft in texture, flexible without cracking when folded, and have a long shelf life. A 5-point subjective rollability test developed at Texas A&M University is normally performed to determine shelf stability of flour tortillas, which is the number of days until the rollability score reaches 3 on a descending scale of 5 (no cracking) to 1 (unrollable).

Arise® 5000 was formulated in a flour tortilla formula at a level of 1% to 3% based on flour **(Table 30, Appendix A)**. Its incorporation had a positive effect on the shelf stability **(Table 31)** of the flour tortilla as shown by a significant increase in time (22-26 days) in which the tortilla had an acceptable rollability score compared to the control tortilla (10 days).

Table 31. *Effect of Arise® 5000 on shelf stability of flour tortilla.*

Sample	Shelf stability, days
Wheat flour	10
1% Arise® 5000	22
2% Arise® 5000	24
3%Arise® 5000	26

The specific volume of flour tortilla made from pastry flour or tortilla flour, but not with bread flour, was improved by the addition of 3% Arise® 5000 **(Table 32)**. Flour tortilla prepared from a pastry flour but not with a tortilla flour or bread flour showed improved specific volume with 3% added Arise® 6000. Compared to the control flour, the shelf stability of flour tortilla based on rollability scores significantly improved (20-26 days vs 10-18 days) with the addition of 3% Arise® 5000 or Arise® 6000. In bread and flour tortilla production, Arise® 5000 and Arise® 6000 share common benefits, which are summarized in **Table 33**.

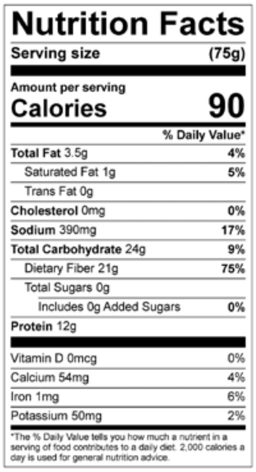


Figure 27. *Nutrition Facts of high-protein, low-net carbohydrate bread generated by Genesis R&D software program.*

LAYER CAKE

Most layer-cake formulas contain egg which represents a significant percentage of the total ingredient cost. The price of egg can fluctuate broadly because the supply can be impacted by a bird flu epidemic. In a baking study, liquid whole egg was totally replaced by 2, 3 or 5% Arise® 8200 in a layer-cake formula (Table 34, Appendix A).

Table 32. *Effect of added 3% Arise® 5000 or 3% Arise® 6000 on quality of flour tortilla made from pastry flour, tortilla flour or bread flour.**

Flour Type/Arise®	Specific Volume cm3/g	Shelf Stability** days
Pastry Flour	1.42	10
Arise® 5000	1.47	22
Arise® 6000	1.52	20
Tortilla Flour	1.46	12
Arise® 5000	1.60	26
Arise® 6000	1.39	24
Bread Flour	1.54	18
Arise® 5000	1.50	26
Arise® 6000	1.46	26

***Source:** Pascut et al 2004
**Shelf stability was based on subjective rollability test.

Table 33. *Summary of shared benefits of Arise® 5000 and Arise® 6000 in bread and flour tortilla products.*

Shared Benefits	Arise® 5000	Arise® 6000
Increases dough extensibilty	√	
Increases water absorption of dough	Comparable	Comparable
Decreases dough mixing time	√	
Slackens dough out of mixer, but recovers to optimum	Comparable	Comparable
Increases loaf volume of bread		√
Provides good internal structure (grain and crumb firmness)	Comparable	Comparable
Increases flour tortilla diameter and rollability scores	Comparable	Comparable
Improves shelf-life of flour tortillas	√	

Judging from the cake height at five different points, the 2-5% level of addition of Arise® 8200 improved the volume of the resulting cakes indicating that Arise® 8200 is a suitable total replacer for liquid whole egg in layer-cake formulations (Fig. 28).

Figure 28. *Effect of replacement of whole eggs by Arise® 8200 on volume of layer cake.*

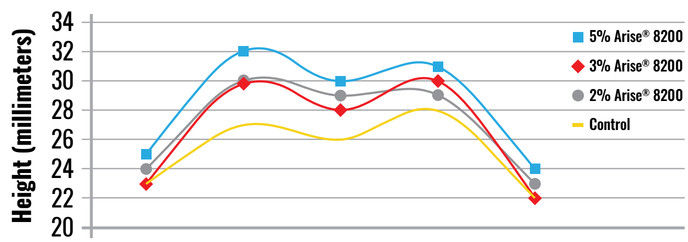


Table 35. *Effect of four Arise® wheat protein isolates at 1.5% level on volume of cake muffins as judged by height.*

Protein Source	Height, cm
Control Wheat Flour (No Additive)	42
Arise® 5000, 1.5%	43
Arise® 6000, 1.5%	46
Arise® 8100, 1.5%	38
Arise® 8200, 1.5%	48

Key Points of Arise® 8100

- Clean label (no added sulfite)
- Increases dough extensibility
- Decreases dough mix time
- Replaces chemical dough relaxers
- Non-GMO Project Verified

CASE STUDIES IN COMMERCIAL BAKERIES ▶ Continued

OTHER BAKERY PRODUCTS

The performance of a number of the Arise® wheat protein isolates were evaluated in cake muffins, English muffins, biscuits and croissants. All results were positive. As judged by the height of cake muffins, three of the four Arise® wheat protein isolates when added at 1.5% outperformed the control, and Arise® 8200 ranked the best (Table 35). When used at 1.5% level in English muffins, four Arise® wheat protein isolates yielded a higher volume compared to the control with Arise® 8100 recording the highest volume (Table 36). Based on average height and diameter of biscuits, Arise® 8100 and Arise® 8200 at 0.5% usage level performed better than the control (Table 37). Four Arise® wheat protein isolates added at 1.0% level in croissants registered higher product height than the control, again with Arise® 8200 displaying the highest product height (Table 38).

Table 36. *Performance of four Arise® wheat protein isolates at 1.5% level on English muffins.*

Protein Source	Volume, cc
Control Wheat Flour (No Additive)	80
Arise® 5000, 1.5%	94
Arise® 6000, 1.5%	84
Arise® 8100, 1.5%	99
Arise® 8200, 1.5%	89

Table 38. *Effect of added Arise® wheat protein isolates at 1.0% level on volume of croissants as judged by peak height.*

Protein Source	Peak Height, cm
Control Wheat Flour (No Additive)	2.5
Arise® 5000, 1.0%	3.0
Arise® 6000, 1.0%	3.0
Arise® 8100, 1.0%	3.3
Arise® 8200, 1.0%	3.5

Table 37. *Comparison of the effect of vital wheat gluten, Arise® 8100 and Arise® 8200 at 0.5% level on height and diameter of biscuits.*

Protein Source	Average Height, in	Average Diameter, in
Control Wheat Flour (No Additive)	1.0	2.2
Vital Wheat Gluten, 0.5%	1.25	2.5
Arise® 8100, 0.5%	1.4	2.4
Arise® 8200, 0.5%	1.3	2.3

CASE STUDIES IN COMMERCIAL BAKERIES

The following case studies were documented from actual bakery plant trials involving the incorporation of Arise® 5000 or Arise® 6000 in several bakery products.

1. Sourdough Bread

Case #1 demonstrates the ability of Arise® 6000 to prevent dough failure during the production of one-pound sourdough loaves in a no-time system. The bread base contained acetic, lactic and fumaric acids to contribute to the sour flavor. The total weight of the dough in the production batch was 1200 pounds. The dough was mixed for 3 minutes on low speed and 13 minutes on high speed with proper development and typical gluten film formation. The dough was divided into 19-oz pieces on a knife and ram divider with an inverted cone rounder. The pieces relaxed on an open belt for two minutes and were then conveyed to a sheeter and a straight-grain moulder where problems began to occur. At the halfway point, buckiness developed, causing misshapen loaves with rough, mottled surfaces. The dough was proofed for one hour. The shape and appearance of first half of the loaves were acceptable. Tearing appeared midway through the dough. The last third of the loaves had three one inch-deep tears per loaf and exhibited discoloration after baking. Twenty-five percent of the run had to be discarded.

When 1.5% Arise® 6000 was added, the dough batch was increased from 1200 to 1800 pounds to demonstrate effectiveness. The formula remained the same as the control except for the addition of Arise® 6000. Mix time was reduced one minute and dough development and gluten film were optimized. During make-up, there were no problems with rough surfaces or dough pieces with poor symmetry. At the end of a one-hour proof, all dough pieces were smooth and symmetrical.

After baking, all loaves had improved volume with smooth crusts. The addition of 1.5% Arise® 6000 improved dough line tolerance, color, and volume, while reducing production waste.

2. Hamburger Buns

Case #2 demonstrates the benefits that Arise® 5000 deliver to automated high-speed bakery systems where optimized dough weight and rapid throughput are demanded by foodservice customers. An 1800-pound hamburger bun dough was pumped into separate rotary dividers that fed two bun lines. The dough became bucky and difficult to process during the last fourth of the run. Arise® 5000 at a 1.5% level was added to the test dough along with 1.5% water. L-Cysteine was removed from the formula, and the mix time was reduced from nine minutes to eight minutes.

One divider broke down, leaving the other divider to process 1800 pounds of dough. Arise® 5000 stabilized the dough during the entire process. The test dough ran extremely well and showed no signs of gassiness or buckiness. The bakers commented that they would not have been able to finish the entire dough or have met specifications as easily without the Arise® 5000.

Improvements in bun volume, smoother break and shred, and a whiter, tighter crumb with finer, more uniform cell structure were noted. The product exceeded the specifications.

3. Italian Bread

Case #3 demonstrates the ability of Arise® 6000 to improve loaf quality. The problems with Italian hearth bread are the shrinking and wrinkling that become pronounced after cooling and freezing. Adjustments to the formula, absorption, mix time, and bake time were unsuccessful. After adding 1.5% Arise® 6000 together with 1.5% water, and following the same mix and proof procedures, the dough was observed to be slightly softer, pliable and extensible. After baking, less shrinkage or deformation of bread was noted. After the freezing operation, the quality of loaves with 1.5% Arise® 6000 was dramatically improved over the control loaves.

4. Natural Sourdough Bread

Case #4 demonstrates the effectiveness of Arise® 6000 in enhancing dough flow and freezer stability. The commercial bakery had a two-pound sourdough square (pan bread) that required more pan flow to the corners and more volume to meet specifications. The simple formula used ascorbic acid and a percentage of natural sourdough starter. Standard procedures included mixing 1 minute at low speed and 12 minutes at high speed with rotary dividing and rounding on a long rounding board, hand panning, and a four-hour proof. The control dough showed signs of weakness out of the proof box, especially near the end of each batch, with severe gas bubbles on the dough surface and some settling at transfer. After a partial bake to a light brown color, ventilated cooling and blast freezing, the surfaces exhibited some cracking.

When 1.5% Arise® 6000 was added to the formula together with 1.5% water, the mix time was reduced one minute and the dough development improved despite apprehensions that it might be too slack to process. By the time the dough had been divided and rounded, the test dough felt like the control dough. No additional tackiness or extensibility was noted. After proofing, no loaves exhibited weakness through settling or gas bubbles as observed before. Dough flow to the corners also improved along with side definition. After baking, the bread color and volume both improved and the crust did not crack during freezing. The addition of 1.5% Arise® 6000 improved the machinability, dough strength, volume, pan flow and color while preventing freezer damage.

5. English Muffins

Case #5 demonstrates that Arise® 6000 can improve dough porosity and flow for high-moisture formulas. In a high- speed dough system (where fluid dough is pumped to inline dividers), mixing time and ingredient composition are critical for proper dough-piece flow and porosity. In this case, L- cysteine and sodium stearoyl lactylate were removed from the regular formula, and 1.5% Arise® 6000 together with 1.5% water were added. Mixing time was reduced by one minute. Line efficiencies improved, and since the mixer was no longer the bottleneck for the dividers, the line ran more smoothly. No apparent problems were noted on the line. Less sticking on the rounding bars was observed and fewer dough balls hung up on the zigzag boards, which indicate improved line performance. The finished products with 1.5% Arise® 6000 showed improved griddle flow, volume

CASE STUDIES IN COMMERCIAL BAKERIES ▶ Continued

and porosity. Even though sodium stearoyl lactylate was removed, the English muffins with the Arise® 6000 had a less crumbly texture, and the crumb had a whiter appearance. The shelf life of the test product scored higher than the control muffin.

6. Hot Dog Buns

Case #6 demonstrates the ability of Arise® 6000 to improve dough extensibility for small dough pieces over a longer time period. In running hot dog buns, a baker faced time problems when the last fourth of a 1000-pound dough deteriorated and make-up was poor through the divider. The dough became tight, gassy and bucky. As the dough aged, product quality fell. The made-up dough in the pan was rough, non-extensible and did not fill the pans. After baking, the final portion did not meet specifications.

The quality improved when 1.5% Arise® 6000 was added and several other ingredients were removed. The formula change provided cost savings and better quality. The control contained three different dough conditioners, a mono and diglyceride/enzyme blend and 3.0% wheat gluten. Mixing time was reduced by two minutes, two dough conditioners were removed, the mono and diglyceride/enzyme blend was removed, the sodium stearoyl lactylate was reduced from 0.50% to 0.25%, and 1.0% of the wheat gluten was removed.

The 1.5% Arise® 6000 provided consistently good dough characteristics throughout the run and did not become bucky, rough, or non-extensible like the control. The final product was very comparable to the control, but produced more consistent buns from beginning to end. The buns with Arise® 6000 had similar volume but a tighter, whiter crumb. The removal of half of the sodium stearoyl lactylate did not compromise the shelf life. It is interesting to note that Arise® 6000 produced the same softness without expensive enzymes.

PASTA AND NOODLES

Pasta

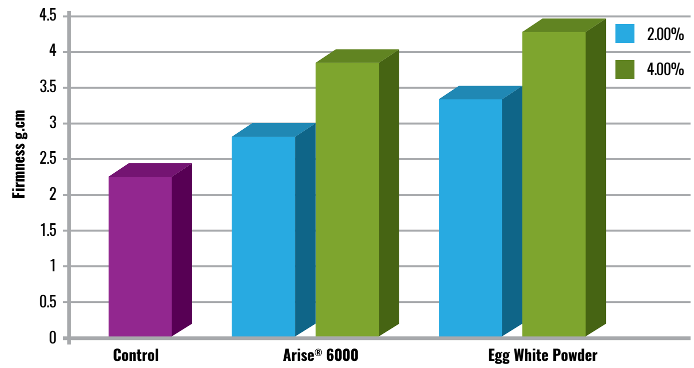
Protein quantity and quality are the most important factors affecting pasta quality. The structure of shaped pasta consists of starch granules and other flour components enveloped by a three-dimensional gluten network. The strength of this network impacts dough rheology that influences processing, the rigidity of the pasta before, during, and after drying, and cooking quality. Utilization of additives such as wheat gluten, whole eggs, egg whites or whey proteins has shown improvements in pasta quality. While egg and egg white products are known for their nutritional value and performance, pasta manufacturers are looking for alternative additives due to the high cost of egg products, allergy issues, and microbial contamination problems. Thus, wheat proteins represent an attractive substitute for egg proteins in pasta.

A study was conducted at North Dakota State University to assess the performance of egg white powder and Arise® 6000 in retorted spaghetti. Both proteins were tested at 2% and 4% levels. After adding the protein to semolina, each mixture was blended for 15 minutes in a twin shell cross-flow dry blender, an appropriate amount of water (~31.5%) was added with continued mixing, and the crumbly dough was then processed into spaghetti strands on a DeMaco Pasta Press fitted with a Teflon-coated die having 0.157 cm openings. A high-temperature drying cycle was used to dry the spaghetti strands. The spaghetti samples in tomato sauce were still-retorted using a sterilizing value of 1. The firmness of retorted spaghetti was determined 24 hours after processing using a Texture Analyzer.

The addition of Arise® 6000 or egg white powder had a positive effect on the firmness of retorted spaghetti **(Fig. 29)**. At the 2% or 4% fortification level, Arise® 6000 showed a 28.1% and 78.3% increase, respectively, in firmness of retorted spaghetti over the control. Addition of 2% and 4% egg white powder increased the firmness by 53.2% and 99.5%, respectively. When added at 2 or 4% level in spaghetti in another experiment, Arise® 6000 out-performed Arise® 5000 and Arise® 8000 based on reduction of cooking loss and increased textural firmness of cooked spaghetti **(Table 39)**.

In another project with North Dakota State University, eight blend compositions consisting of an analog flour (i.e. a mixture of vital wheat gluten or Arise® 6000 and Fibersym® RW) and semolina were prepared **(Table 40, Appendix A)**. The blends were processed yielding fiber-enhanced spaghetti and evaluated for

Figure 29. *Effects of 2% and 4% Arise® 6000 or egg white powder on firmness of retorted spaghetti.*



their cooking properties. Compared to the control spaghetti, cooking time generally increased by 2.0-4.5 minutes in fiber-enhanced spaghetti samples made from the different blends **(Table 41)**. On the other hand, both cooking loss and cooked weight were reduced in spaghetti samples made from the different blends. These results can be explained by the strong protein network and the restricted swelling of Fibersym hindering water absorption and limiting the escape or diffusion of amylose from the granules. Cooked spaghetti samples from Blends 1-6 tended to be less firm than the control spaghetti. Firmer spaghettis were made from Blends 7-8 that contain 12-13% Arise® 6000, 48-52% Fibersym and 35-40% semolina.

Wheat Noodles

Wheat noodles are characterized by thin strips slit from sheeted doughs that have been made from wheat

Table 39. *Effects of added Arise® 5000, Arise® 6000 or Arise® 8000 at 2% or 4% level on spaghetti quality.*

	Dry Spaghetti Color			Cooking Parameters			
Protein Source	**L**	**a**	**b**	**Time, min.**	**Weight, g**	**Loss, %**	**Firmness, g**
Control	59.67	3.99	35.70	10.0	29.5	5.3	5.6
2% Arise® 5000	59.83	4.58	36.09	10.0	28.2	5.2	5.3
4% Arise® 5000	59.84	4.22	35.43	10.0	27.8	5.4	6.1
2% Arise® 6000	60.02	4.24	35.67	10.0	27.8	5.3	5.9
4% Arise® 6000	59.08	4.50	35.62	9.5	27.3	4.8	6.9
2% Arise® 8000	59.89	4.36	35.57	9.5	27.6	5.2	6.3
4% Arise® 8000	60.90	3.88	35.93	10.0	27.9	5.3	6.7

PASTA AND NOODLES ▶ Continued

flour, water, and common salt or alkaline salt. Noodles are made not only from wheat flour but also from other raw materials such as buckwheat flour, a legume starch, and rice. Buckwheat noodles, like wheat noodles, are cut from a mixed/sheeted dough, but starch noodles ("glass" noodles) and rice noodles are made by unique processes. Noodles are often consumed in a water-rich application such as soup.

Three types of Asian noodles, namely white salted, chuka-men, and instant fried **(Tables 42-44, Appendix A)**, were prepared in which 10% or 30% of the flour was replaced by a 16/84 blend of Arise® 6000 and MGP's Fibersym® RW resistant wheat starch. After preparation, the noodles were photographed as shown in **Figs. 30-32**. The three types of noodles were characterized with acceptable processability and machinability properties. The color of white salted and instant fried noodles were acceptable at both levels of substitution, whereas the yellowness of chuka-men noodle was acceptable at 10%, but not at a 30% substitution level. Water uptake after cooking the three types of noodles appeared to be comparable for the control and the formulation with the 10% substitution level, but a marked decrease was observed for the formulation with a 30% substitution level. Sensory evaluation of the three types of noodles indicated that 10% and 30% substitution levels produced noodles with the desired texture (bite, springiness, and mouthfeel) after cooking.

In a separate study, Arise® 6000 added at a 2% level in white salted noodles yielded higher texture scores in hardness, springiness, cohesiveness, and chewiness among the wheat protein isolates and vital wheat gluten compared to the control (no additive) **(Table 45)**. Hardness and chewiness scores of chuka-men noodles are markedly higher for those formulated with 2% Arise® 5000 and Arise® 6000 compared to the control and the other two wheat proteins **(Table 46)**. With instant fried noodles, 2% of Arise® 5000 and Arise® 6000 have

Table 41. *Cooking properties of fiber-enhanced spaghetti made from blends shown in Table 43.*

Sample No.	Optimum Cooking Time, min	Cooking Loss, %	Cooked Weight, g	Firmness, gcm
Control	11.0	5.6	28.4	7.2
Blend 1	15.5	3.2	22.6	6.9
Blend 2	15.0	3.4	22.6	6.2
Blend 3	14.5	4.6	23.1	6.8
Blend 4	13.5	4.4	23.8	6.1
Blend 5	13.0	3.6	22.1	6.4
Blend 6	13.5	4.0	23.0	6.1
Blend 7	13.5	4.0	23.0	7.3
Blend 8	14.0	4.0	23.1	8.0

Figure 30. *Appearance of white salted noodles with 0% (Control), 10% or 30% substitution of the flour by a blend of Arise® 6000 and Fibersym® RW (16:84 ratio).*

Figure 31. *Appearance of chuka-men noodles with 0% (Control), 10% or 30% substitution of the flour by a blend of Arise® 6000 and Fibersym® RW (16:84 ratio).*

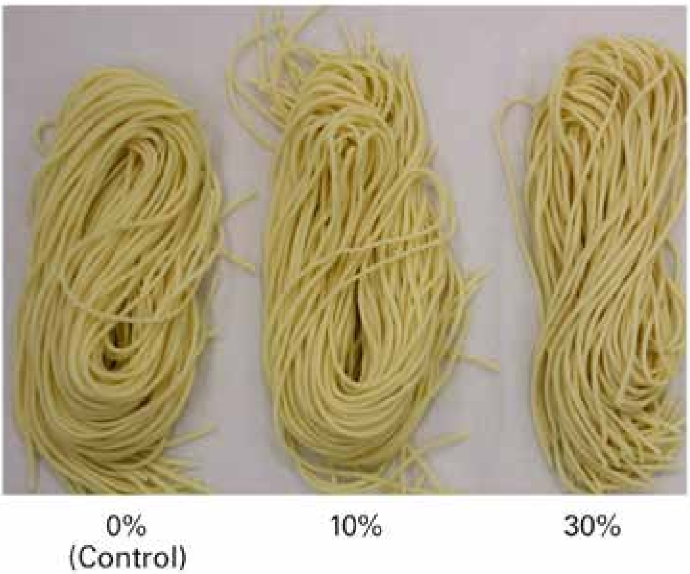


Figure 32. *Appearance of instant fried noodles with 0% (Control), 10% or 30% substitution of the flour by a blend of Arise® 6000 and Fibersym® RW (16:84 ratio).*

comparable, but better texture scores than Arise® 8000, vital wheat gluten or the control sample **(Table 47)**.

PREDUST IN COATED FOODS

Arise® 5000 and Arise® 6000 were evaluated for partial or full replacement of egg white powder in two commercial predust formulas for coated foods. Commercial predust formula A consisted of 75% all-purpose flour, 15% vital wheat gluten, 6% egg white powder (or Arise® protein) and 4% salt **(Table 48, Appendix A)**. The ingredients in commercial predust formula B consisted of 92.5% all-purpose flour, 5% egg white powder (or Arise® protein), 2% salt and 0.5% baking powder **(Table 49, Appendix A)**. Chicken tenders were used as the substrate for the coating study. The batter mix, cracker meal for breading, and egg white powder were either purchased from a local store or requested from a commercial source. The procedure consisted of applying the predust to two pieces of chicken tenders, followed by dipping in the adhesion batter, and finally coating with cracker meal. Percent pick-up was measured. The coated chicken tenders were fried in oil for 3-4 minutes at 375°F. The pieces were weighed after frying to calculate percent yield. After 2 minutes, the taste and eating quality was evaluated and the adhesion of coating on the chicken tenders was determined.

At 50% substitution of egg white powder by Arise® 5000 or Arise® 6000, the percent adhesion using commercial predust formula A was as good and even slightly better than the full egg white control **(Table 50)**. Commercial predust formula B yielded similar adhesion performance between egg white powder and the two wheat protein isolates **(Table 51)**. The percent pick-up in both predust formulas was within range, with Arise® 6000 showing higher pick-up. Yield was slightly better for egg white powder in both predust formulas.

The 75% level of egg white replacement by Arise® protein appears to give the best adhesion scores for Arise® 5000 and Arise® 6000 in both commercial predust formulas **(Tables 50 and 51)**. Comparable percent pick-up was noted with no apparent trend among the three samples. Egg white powder tended to have a slightly better yield than the two wheat protein isolates.

PASTA AND NOODLES ▶ Continued

Table 45. *Effects of vital wheat gluten or Arise® wheat protein isolates on texture of cooked white salted noodles.*

Ingredients	Hardness, g	Springiness, %	Cohesiveness	Chewiness, g	Weight gain, %
Control	1221.7	95.4	0.625	728.4	119.5
2% Vital wheat gluten	1357.1	92.4	0.639	801.3	113.7
2% Arise® 5000	1366.1	96.1	0.607	797.8	112.2
2% Arise® 6000	1381.0	97.8	0.634	857.4	113.6
2% Arise® 8000	1362.9	93.8	0.636	812.7	112.0

Table 46. *Effects of vital wheat gluten or Arise® wheat protein isolates on texture of cooked chuka-men noodles.*

Ingredients	Hardness, g	Springiness, %	Cohesiveness	Chewiness, g	Weight gain, %
Control	1184.3	92.1	0.620	676.2	111.6
2% Vital wheat gluten	1126.1	90.5	0.639	651.3	100.0
2% Arise® 5000	1243.0	91.7	0.622	709.1	103.8
2% Arise® 6000	1234.6	91.5	0.629	710.5	99.9
2% Arise® 8000	1153.7	90.8	0.627	656.9	108.1

Table 47. *Effects of vital wheat gluten or Arise® wheat protein isolates on texture of cooked instant fried noodles.*

Ingredients	Hardness, g	Springiness, %	Cohesiveness	Chewiness, g	Weight gain, %
Control	1441.0	94.9	0.633	865.7	126.3
2% Vital wheat gluten	1394.4	87.1	0.673	822.0	128.3
2% Arise® 5000	1558.7	94.3	0.641	942.1	131.6
2% Arise® 6000	1490.4	95.2	0.650	921.5	134.1
2% Arise® 8000	1309.7	81.5	0.662	707.2	134.9

At 100% replacement of egg white powder, and using commercial predust formula A, the percent pick-up and percent yield appeared comparable among the three samples **(Table 50)**. The percent adhesion was acceptable for the two wheat protein isolates, but not as good as the egg white formula. Both Arise® 5000 and Arise® 6000 performed poorly compared to egg white powder in commercial predust formula B **(Table 51)**.

In all of the egg white powder replacements described above, no apparent differences in taste and eating quality were perceived among the coated chicken tender samples after frying. Both Arise® 5000 and Arise® 6000 performed satisfactorily as egg white replacers at 50% to 75% substitution levels in the two commercial predust formulas for coated chicken fingers.

Table 50. *Egg white replacement of predust formula A using Arise® 5000 or Arise® 6000 and their performance in coated chicken tenders.*

Sample	% Egg White Replacement	% Pick-up	%Yield	% Adhesion
Control	0	30.9	90.7	90
Arise® 5000	50	28.6	89.5	95
Arise® 6000	50	33.2	89.1	95
Control	0	30.6	88.8	100
Arise® 5000	75	32.9	87.3	100
Arise® 6000	75	30.6	-	100
Control	0	26.2	87.6	100
Arise® 5000	100	24.9	87.9	90
Arise® 6000	100	27.9	86.9	95

Table 51. *Egg white replacement of predust formula B using Arise® 5000 or Arise® 6000 and their performance in coated chicken tenders.*

Sample	% Egg White Replacement	% Pick-up	%Yield	% Adhesion
Control	0	30.1	89.6	100
Arise® 5000	50	30.2	88.7	100
Arise® 6000	50	31.8	88.7	100
Control	0	31.1	87.7	100
Arise® 5000	75	33.9	86.9	100
Arise® 6000	75	33.3	86.5	100
Control	0	30.3	86.8	90
Arise® 5000	100	29.4	86.8	70
Arise® 6000	100	29.6	87.2	70

Key Points of Arise® 8200:

- Clean label (no added sulfite)
- Increases dough extensibility
- Decreases dough mix time
- Replaces chemical dough relaxers
- Non-GMO Project Verified

APPENDIX A

Table 1. *Average amino acid composition[a] of wheat gluten 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

Table 7. *Effects of added 3% vital wheat gluten, 3% Arise® 5000 or 3% Arise® 6000 on mixograph quality of three types of wheat flour.*

Ingredients	Mixing Time, min	Mixing Resistance, MU[a]
Pastry Flour	5.0	2.5
3% Vital wheat gluten	4.0	4.8
3% Arise® 5000	2.5	4.8
3% Arise® 6000	3.2	4.5
Tortilla Flour	4.8	4.2
3% Vital wheat gluten	3.0	5.8
3% Arise® 5000	2.0	5.5
3% Arise® 6000	2.0	5.8
Bread Flour	4.0	4.8
3% Vital wheat gluten	4.5	4.8
3% Arise® 5000	2.5	4.5

Adapted from Pascut et al 2004
[a]**Mixograph Units**

Table 8. *Influence of four production batches of Arise® 5000 on farinograph[a] quality of wheat flour at 1.5% level.*

Ingredients	Absorption %	Peak time, min	Stability, min	MTI, BU[b]
Control	66.9	10.0	16.0	20
Arise® 5000, Lot A	69.4	8.5	11.0	30
Arise® 5000, Lot B	69.5	8.5	9.0	40
Arise® 5000, Lot C	70.0	8.5	10.0	35
Arise® 5000, Lot D	70.0	8.5	9.5	30

[a]Farinograph analysis by CII Laboratory Services
[b]**MTI, BU** = Mixing Tolerance Index, Brabender Units

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Table 3. *Nutrient information per 100 grams of the different Arise® wheat protein isolate products.*

Parameters	Arise® 5000	Arise® 5500	Arise® 6000	Arise® 8000	Arise® 8100	Arise® 8200
Water, g	5.65	3.96	4.80	7.46	4.19	4.86
Calories	399.9	407.3	397	391	408.1	399.8
Protein, g	77.92	79.86	79.6	80.5	79.29	75.97
Total Fat, g	4.9	5.36	5.55	4.82	5.55	5.53
Saturated Fat, g	1.12	1.12	1.11	1.16	1.12	1.09
Monounsaturated Fat, g	0.84	0.82	0.82	0.78	0.87	0.87
cis-cis Polyunsaturated Fat, g	2.71	3.17	3.37	2.61	3.30	3.31
trans Fat, g	<0.10	<0.10	0.01	0.06	<0.10	<0.10
Carbohydrates, g	11.03	9.96	7.13	6.48	10.22	11.55
Total Dietary Fiber, g	<0.47	2.24	<0.1	<0.10	<0.47	<0.47
Total Sugars, g	<0.1	<0.10	1.38	0.45	0.56	0.27
Ash, g	0.50	0.86	2.92	0.74	0.75	2.09
Calcium, mg	65.2	6.33	67.2	47.8	91.5	85.5
Iron, mg	3.9	4.4	3.35	4.21	5.1	3.5
Sodium, mg	87.7	127	913	12.4	60.3	629
Potassium, mg	40.7	51.4	29.2	31.3	58.6	54.0
Cholesterol, mg	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vitamin D, ug	<1	<1	<1	<1	<1	<1
Vitamin A, IU	100	100	-	100	100	100
Vitamin C, mg	<1	<1	-	<1	<1	1.11

APPENDIX A ▶ Continued

Table 13. *Extensibility and resistance to extension at three resting periods of wheat flour with varying levels (1.0-3.0%) of Arise® 6000 as determined in an extensograph.*

		45 min.		90 min.		135 min.	
Protein Source	**Level %**	**Res***	**Ext***	**Res***	**Ext***	**Res***	**Ext***
Control Wheat Flour (No Additive)	0	787	189	1022	176	1190	168
Arise® 6000	1.0	776	252	1003	186	1113	176
	2.0	722	229	947	185	1053	179
	3.0	673	197	1019	189	1028	153

***Res** = Resistance to Extension (EU); **Ext** = Extensibility (mm)

Table 17. *Alveograph data of wheat flour containing 1%, 3%, or 5% of Arise® 5000.*

	Extensibility, mm	Resistance to Extension, mm H_2O
Control	79	121
1% Arise® 5000	93	112
3% Arise® 5000	121	92
5% Arise® 5000	115	87

Table 18. *Alveograph data of wheat flour containing 1%, 3%, or 5% of Arise® 5500.*

Protein Source	Extensibility, mm	Resistance to Extension, mm H_2O
Control Wheat Flour (no additive)	79	121
1% Arise® 5500	84	114
3% Arise® 5500	80	116
5% Arise® 5500	74	126

Table 19 *Alveograph data of wheat flour containing 1%, 3% or 5% of Arise® 8000.*

Additive	Extensibility, mm	Resistance to Extension, mm H_2O
No additive	79	121
1% Arise® 8000	68	129
3% Arise® 8000	76	142
5% Arise® 8000	79	167

Table 24. *Sponge and dough white pan bread formulas[a] with different levels (1.0-2.0%) of Arise® 5000 or Arise® 6000.*

	Arise® 5000	Arise® 6000
Ingredients	**Baker's Percent**	
SPONGE		
Bread Flour	70.0	70.0
Compressed yeast	2.0	2.0
Yeast food (non-bromated)	0.5	0.5
Water	42.0	42.0
DOUGH		
Bread Flour	30.0	30.0
Arise® 5000	1.0, 1.5, or 2.0	-
Arise® 6000	-	1.0, 1.5, or 2.0
High-fructose corn syrup	10.0	10.0
Soybean oil	2.0	2.0
Salt	2.0	2.0
Calcium propionate	0.12	0.12
Water	Variable	Variable

Source: AIB study
[a]**Formulas** = Expressed in Baker's Percent

Table 26. *Whole wheat bread formulas[a] comparing the effects of vital wheat gluten or Arise® 6000 on bread quality.*

	Control	Vital Wheat Gluten	Arise® 6000
Ingredients			
Whole Wheat Flour	100.0	100.0	100.0
Vital Wheat Gluten	6.0	6.0	6.0
Water	75.0	75.0	75.0
Yeast	6.0	6.0	6.0
Yeast food	0.5	0.5	0.5
Ethoxylated monoglyceride	0.75	0.75	0.75
Sodium stearoyl lactylate	0.5	0.5	0.5
Vital Wheat Gluten	0	1	0
Arise® 6000	0	0	1
Salt	2.25	2.25	2.25
Brown sugar	8.0	8.0	8.0
Shortening	4.0	4.0	4.0
Calcium propionate	0.3	0.3	0.3
Azodicarbonamide	0.0030	0.0030	0.0030
Ascorbic acid	0.0075	0.0075	0.0075

[a]**Formulas** = Expressed in Baker's Percent

Table 27. *Whole wheat bread formulas[a] containing high protein and high fiber.*

	Whole Red Wheat Flour	Whole White Wheat Flour
Ingredients	**Baker's Percent**	
Whole wheat red flour	32	-
Whole wheat white flour	-	32
Vital Wheat Gluten	20	20
Fibersym® RW	23	23
Arise® 5000	12	12
Soy fiber, FI-1	13	13
Salt	1.9	1.9
Soybean oil	5	5
Sodium stearoyl lactylate	0.35	0.35
Ethoxylated monoglyceride	0.35	0.35
Calcium propionate	0.375	0.375
Granulated sugar	1	1
DATEM	0.35	0.35
Ascorbic acid	0.015	0.015
Compressed yeast	8	8
Sucralose	0.008	0.008
Water	78	80

[a]**Formulas** = Expressed in Baker's Percent

APPENDIX A ▶ Continued

Table 29. *High-protein, low-net carbohydrate bread formula using a blend of Arise® wheat protein isolates, Fibersym® RW and oat fiber as analog flour.*

Ingredients	Amount, Baker's %
Fibersym® RW	51.0
Arise® 8000	24.0
Arise® 5000	13.0
Oat fiber	12.0
Compressed yeast	8.0
Soybean oil	5.0
Salt	1.9
Calcium propionate	0.375
SSL	0.35
DATEM	0.35
Ethoxylated monoglycerides	0.35
Ascorbic acid	0.015
Sucralose	0.008
Water (variable)	77

Table 30. *Formulation of flour tortilla with 1.0%, 2.0% or 3.0% of Arise® 5000.*

Ingredients	Amount, grams
Wheat flour	1000
Salt	15
Sodium bicarbonate	6
Sodium stearoyl lactylate	5
Potassium sorbate	4
Sodium aluminum sulfate	5.8
Fumaric acid	2.4
Shortening	60
Arise® 5000	10, 20, or 30

Table 42. *Formulas of control white salted noodles and those containing blends of Arise® 6000 and Fibersym® RW.*

Ingredients	Control	10% Flour Substitution	30% Flour Substitution
Wheat Flour	100	90	70
Arise® 6000/Fibersym® RW blend (16:84)	0	10	30
Water	28	29	30
Salt	1.5	1.5	1.5

Table 34. *Application of Arise® 8200 as a total egg replacer in a layer cake formula (in grams).*

Ingredients	Control	Arise® 8200	Arise® 8200	Arise® 8200
Cake Flour	100	100	100	100
Condensed Milk	133	133	133	133
Water	33.3	59.8	61.3	64.3
Melted Butter	30	30	30	30
Sugar	20	20	20	20
Vanilla Extract	4	4	4	4
Baking Powder	4	4	4	4
Salt	2	2	2	2
Baking Soda	1	1	1	1
Liquid Whole Eggs	31.3	0	0	0
Arise® 8200	0	2	3	5

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Table 40. *Blends of vital wheat gluten or Arise® 6000 and Fibersym® RW with semolina for fiber-enhanced spaghetti preparation.*

Sample No.	Composition of Blend, %			
	Analog Flour			Semolina
	Vital Wheat Gluten	Arise® 6000	Fibersym® RW	
Control	-	-	-	100
Blend 1	15	-	60	25
Blend 2	14	-	56	30
Blend 3	13	-	52	35
Blend 4	12	-	48	40
Blend 5	-	15	60	25
Blend 6	-	14	56	30
Blend 7	-	13	52	35
Blend 8	-	12	48	40

Table 43. *Formulas of control chuka-men noodles and those containing blends of Arise® 6000 and Fibersym® RW.*

Ingredients	Control	10% Flour Substitution	30% Flour Substitution
Flour	100	90	70
Arise® 6000/Fibersym® RW blend (16:84)	0	10	30
Water	32	33	34
Salt	1	1	1
Potassium carbonate	0.6	0.6	0.6
Sodium carbonate	0.4	0.4	0.4

Table 44. *Formulas of control instant fried noodles and those containing blends of Arise® 6000 and Fibersym® RW.*

Ingredients	Control	10% Flour Substitution	30% Flour Substitution
Flour	100	90	70
Arise® 6000/Fibersym® RW blend (16:84)	0	10	30
Water	33	34	35
Salt	1.5	1.5	1.5
Potassium carbonate	0.1	0.1	0.1
Sodium carbonate	0.1	0.1	0.1
Guar gum	0.2	0.2	0.2
Phosphate salt	0.1	0.1	0.1

Table 48. *Composition of control commercial predust formula **A** and those containing Arise® 5000 or Arise® 6000 to replace 50%, 75% or 100% of egg white powder.*

		Egg White Replacement					
Ingredients	Control	50%	50%	75%	75%	100%	100%
All-purpose flour	75	75	75	75	75	75	75
Wheat gluten	15	15	15	15	15	15	15
Egg white powder	6	3	3	1.5	1.5	0	0
Arise® 5000	0	3	0	4.5	0	6	0
Arise® 6000	0	0	3	0	4.5	0	6
Salt	4	4	4	4	4	4	4

Table 49. *Composition of control commercial predust formula **B** and those containing Arise® 5000 or Arise® 6000 to replace 50%, 75% or 100% of egg white powder.*

		Egg White Replacement					
Ingredients	Control	50%	50%	75%	75%	100%	100%
All-purpose flour	92.5	92.5	92.5	92.5	92.5	92.5	92.5
Egg white powder	5	2.5	2.5	1.25	1.25	0	0
Arise® 5000	0	2.5	0	3.75	0	5	0
Arise® 6000	0	0	2.5	0	3.75	0	5
Salt	2	2	2	2	2	2	2
Baking powder	0.5	0.5	0.5	0.5	0.5	0.5	0.5

APPENDIX B

Figure 11. Typical appearance of the mixograph curve of wheat flour.

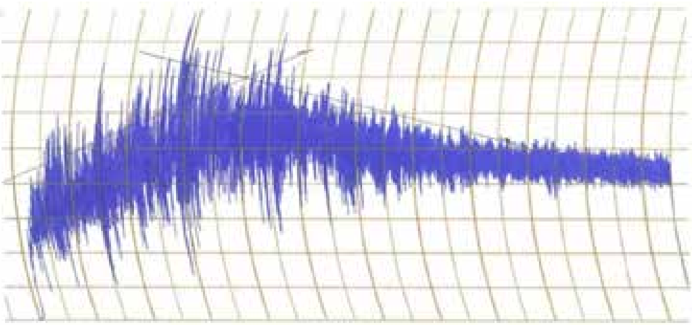


Figure 13. Effect on mixograph curve of wheat flour after incorporating 1%, 3% or 5% of Arise® 6000.

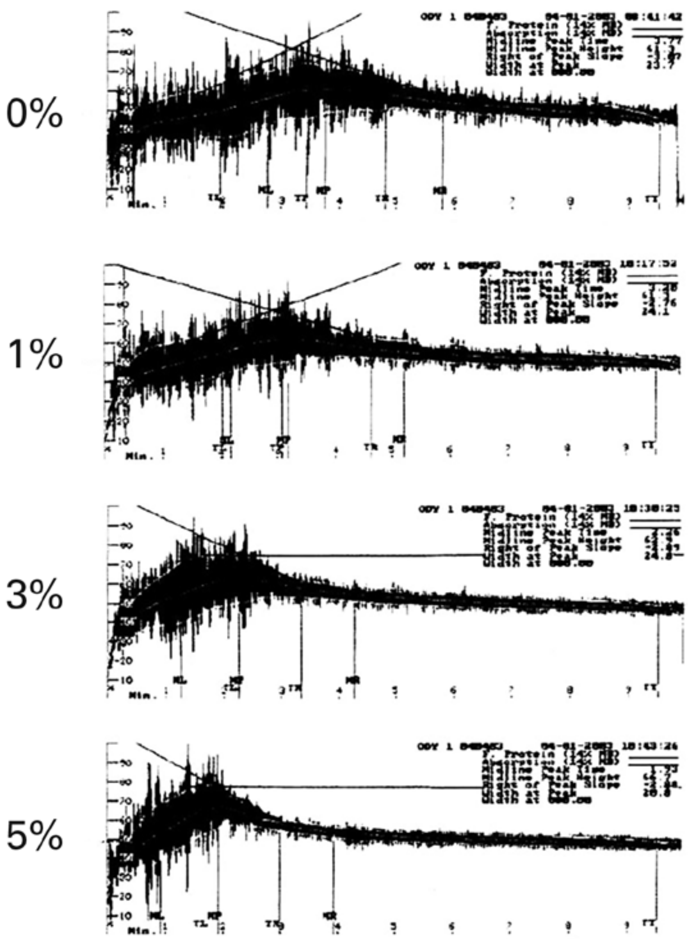


Figure 14. Effect on mixograph curve of wheat flour after incorporating 1%, 3% or 5% of vital wheat gluten.

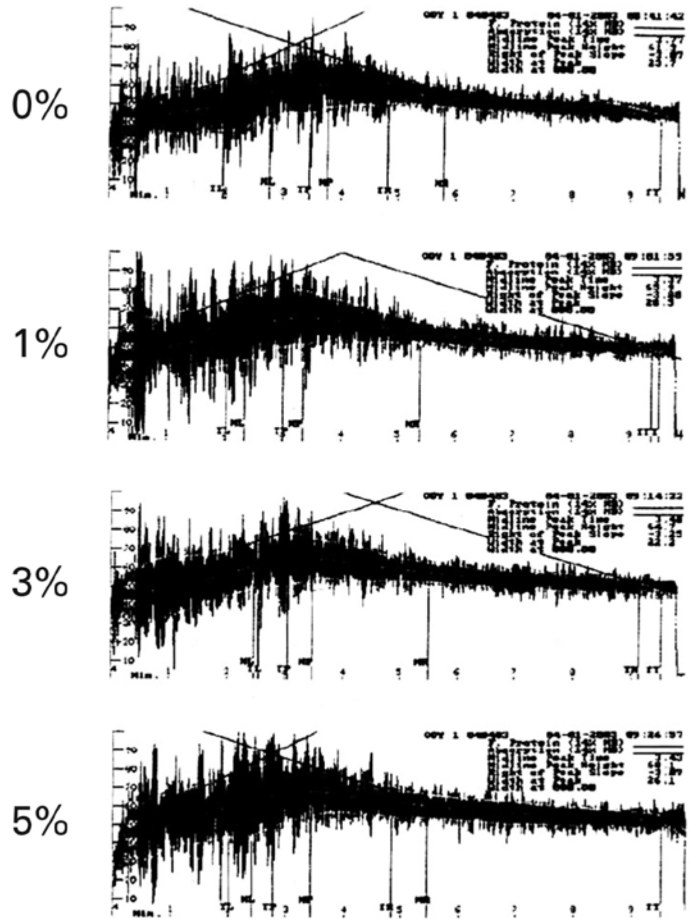


Figure 19. Typical appearance of the farinograph curve of wheat flour.

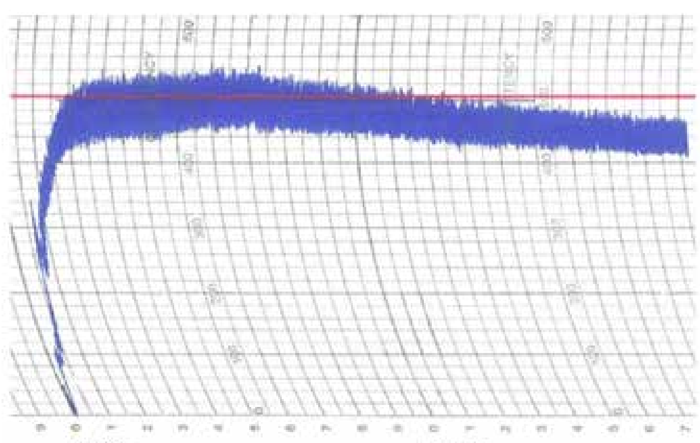


Figure 15. *Effect on mixograph curve of wheat flour after adding 1%, 3% or 5% of Arise® 5500.*

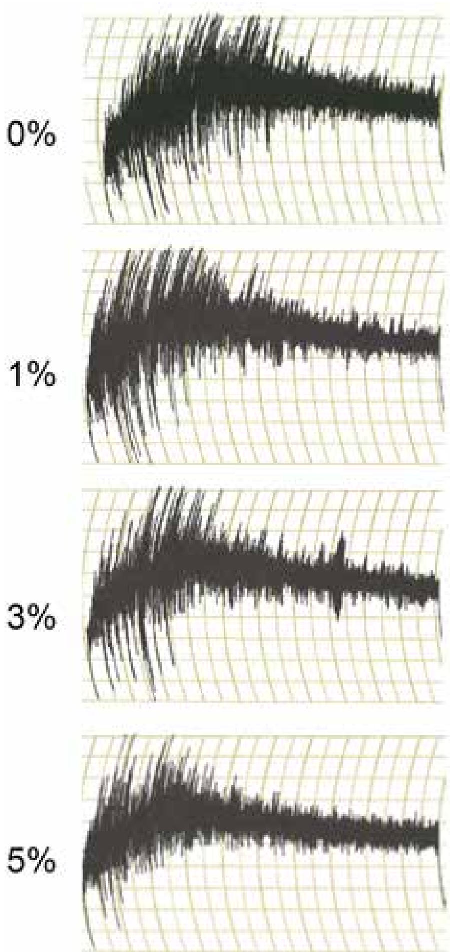


Figure 20. *Typical appearance of the extensograph curves of wheat flour after rest periods of 45, 90, and 135 min.*

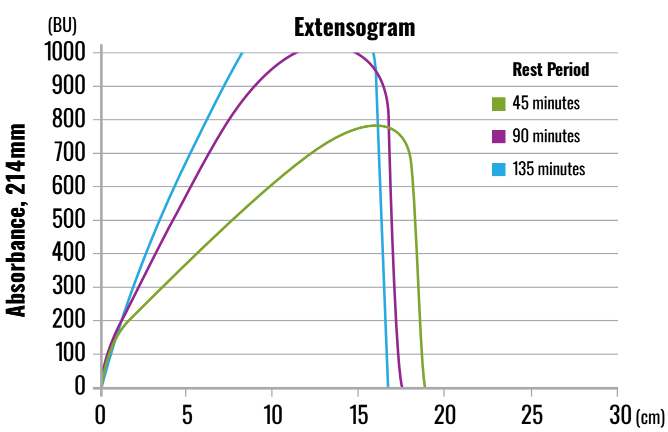


Figure 21. *Graphical representation of the alveograph curves of wheat flour (six measurements).*

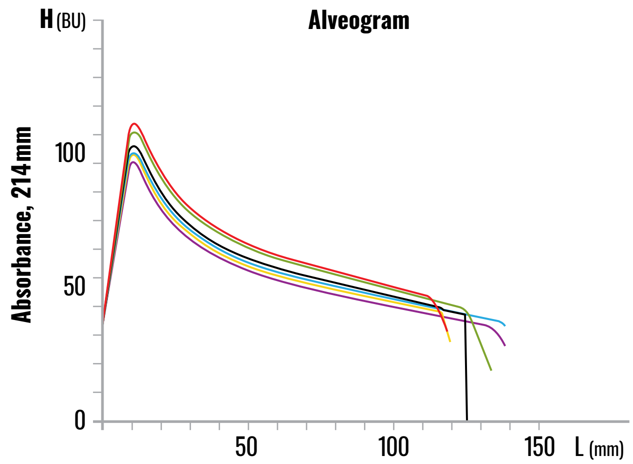
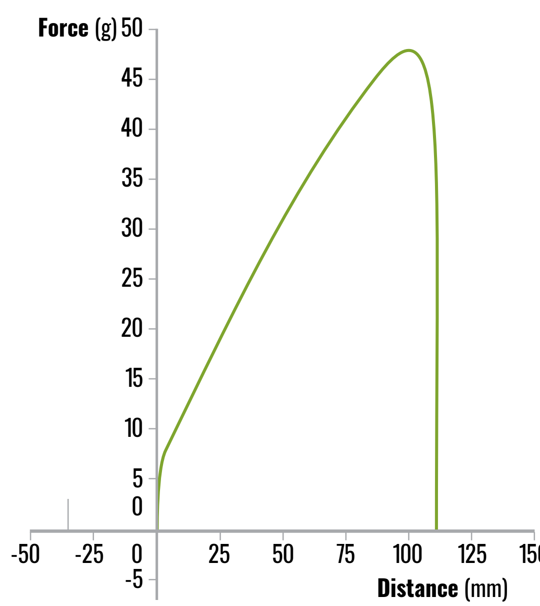


Figure 22. *Typical Kieffer force-distance curve of wheat flour.*



APPENDIX C

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