Arise®

Wheat Protein Isolates

Functional – Nutritional – Convenient – Cost Effective

CREATING BETTER SOLUTIONS...NATURALLY

Table of Contents:

Wheat Protein Isolates

Wheat is a source of nutritionally important macronutrients (starch and protein) 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 in wheat proteins are glutamine, proline and leucine. 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 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.

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 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% protein, calculated on dry basis and using a nitrogen-to-protein conversion factor of 5.7.

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, cross-linking, and oxidation/reduction reactions.

Partial protease hydrolysis 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 bitter peptides as a result of the exposure of hydrophobic amino acid residues near the carboxyl terminal in the polypeptide.

Complete acid hydrolysis of proteins to amino acids is accomplished by treatment with high hydrochloric acid concentration at high temperatures. Modification at a high temperature, but with lower hydrochloric acid concentration results in deamidation, a 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 the glutamine and lysine residues. Treatment with potassium bromate or glucose oxidase results in oxidation of sulfhydryl groups in proteins to disulfide linkages, leading to a dough strengthening effect. Conversely, disulfide bonds in proteins can be broken, yielding sulfhydryl groups in a reduction reaction using L-cysteine or sodium metabisulfite. This reduction reaction leads to increased dough extensibility.

Arise® Family of Wheat Protein Isolates

MGP produces three types of wheat protein isolates, namely Arise® 5000, Arise® 6000 and Arise® 8000. When viewed under a scanning electron microscope, both Arise® 5000 and Arise® 6000 demonstrate irregular shapes and wide distribution of sizes (Figs. 1 and 2).

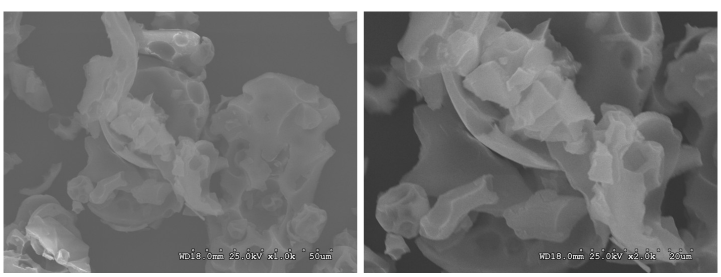
Of the three isolates, Arise® 5000, when hydrated, displays the most extensible and the least elastic properties. Due to its low pH (4.0-4.5) when hydrated in excess water, Arise® 5000 becomes dispersible/soluble in water. It is sulfite-treated and its protein content is equal to or more than 90% (N x 6.25, dry basis).

When hydrated, Arise® 6000 demonstrates more elastic, but less extensible properties than Arise® 5000. It is sulfite-treated and its protein content is a minimum of 85% (N x 6.25, dry basis). Upon hydration of Arise® 6000, the pH 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 among the three Arise® protein isolates. The hydrated pH of Arise® 8000 is approximately neutral.

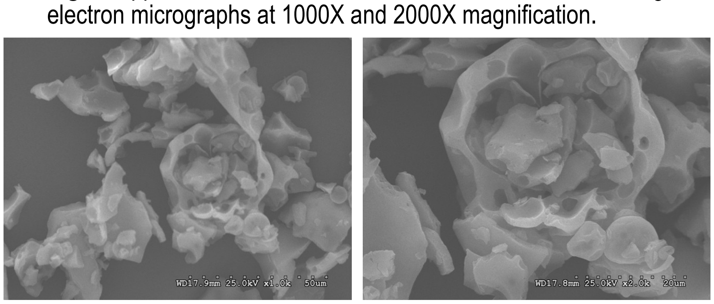
The extensibility and elasticity of hydrated Arise® 5000, Arise® 6000 and Arise® 8000 compared to vital wheat gluten are demonstrated in Fig. 3. The data supporting these hydrated properties of wheat protein isolates are reported under the section on Functionality in Dough Systems, on the following page.

Fig. 1. Appearance of Arise® 5000 as shown in scanning electron micrographs at 1000X and 2000X magnification.



X 1,000 **X 2,000**

Fig. 2. Appearance of Arise® 6000 as demonstrated in scanning electron micrographs at 1000X and 2000X magnification.

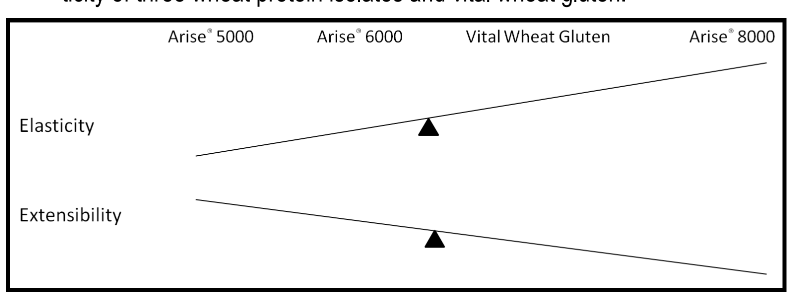


X 1,000 **X 2,000**

Benefits of Arise® 5000

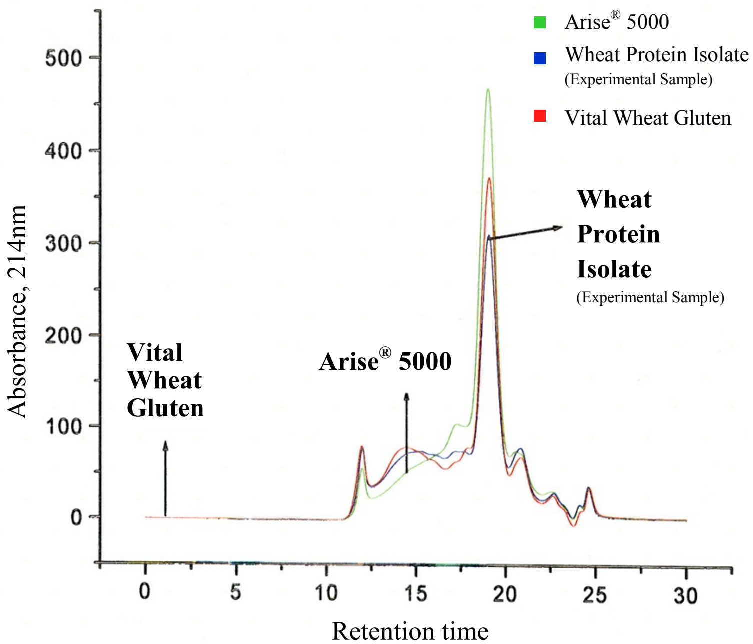
- Decreases dough mix time
- Causes slackening effect on the dough out of the mixer, but dough recovers to optimum at the make-up stage
- Increases dough extensibility
- Improves dough machinability
- Decreases proof time
- Increases bread volume
- Produces internal structure (grain) and crumb firmness comparable to the control bread
- Reduces microwave-induced toughness of pup loaf bread
- Reduces fat absorption in cake donuts
- Results in donut size and cell structure comparable to the control donut
- Reduces pastiness of buttermilk biscuits without adding toughness
- Increases flour tortilla diameter and rollability scores
- Improves shelf-life of flour tortillas

Fig. 3. Comparative ranking of the extent of extensibility and elasticity of three wheat protein isolates and vital wheat gluten.



Typical molecular weight distribution of wheat protein isolates compared to vital wheat gluten is displayed in the SEC-HPLC curves in Fig. 4. Compared to vital wheat gluten, Arise® 5000 demonstrates a reduction of the polymeric glutenin proteins and an increase of the lower molecular weight glutenin proteins.

Fig. 4. Molecular weight distribution profile by SEC-HPLC of vital wheat gluten and wheat protein isolates.



Benefits of Arise® 6000

- Increases dough extensibility
- Increases water absorption
- Decreases dough mixing time
- Causes slackening effect on the dough out of the mixer, but dough recovers to optimum at the make-up stage
- Increases loaf volume of bread
- 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

Benefits of Arise® 8000

- Provides highly concentrated source of protein, averaging ~94%
- Increases resistance to mixing
- Increases resistance to extension (high viscoelasticity)
- Is label friendly

In bread and flour tortilla products, Arise® 5000 and Arise® 6000 share common benefits, which are summarized below in Table 1.

Table 1. Summary of shared benefits of Arise® 5000 and Arise® 6000 in bread and flour tortilla products.

Shared Benefits	Arise® 5000	Arise® 6000
Increases dough extensibility	√	
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	√	

√ - **Indicates greater benefit**

Functionality in Dough Systems

Protein quantity is one of the most important characteristics of wheat flour as it is responsible for the formation of a baked product's framework structure. When the term "protein quality" is used, 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. However, protein quality is best defined in terms of its intended end-use.

Protein quality of wheat flours and the effects of additives are oftentimes estimated by instrumental measurements, but bake tests remain the best method of measuring quality.

As indicators of protein quality, instruments like mixographs, farinographs, extensographs, alveographs, glutomatic, or texture analyzers are employed. These instruments measure mixing time, resistance to mixing (dough strength), water absorption, elasticity, resistance to extension, extensibility, gluten index, and wet and dry gluten content.

Mixograph

A mixograph is an instrument that measures and records the resistance of a dough to mixing. The mixing curve called mixogram is depicted in Fig, 5 (see Appendix C) for a wheat flour sample. The addition of 1%, 3%, and 5% Arise® 5000 to wheat flour progressively decreased dough mixing time as illustrated in Fig. 6 at right. Arise® 6000 exhibited the same mixing time reduction (Fig. 7), whereas vital wheat gluten did not cause a significant change to dough mixing time (Fig. 8, see Appendix C).

The mixograph results presented in Table 2 (see Appendix B) 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 with 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 decreased the mixing time for pastry flour and tortilla flour, but increased mixing time for bread flour. All three protein additives increased the mixing resistance of pastry flour and tortilla flour, but the effect on bread flour was generally inconsistent.

Fig. 6. Effects on mixograph curves of wheat flour after incorporating 1%, 3% and 5% Arise® 5000.

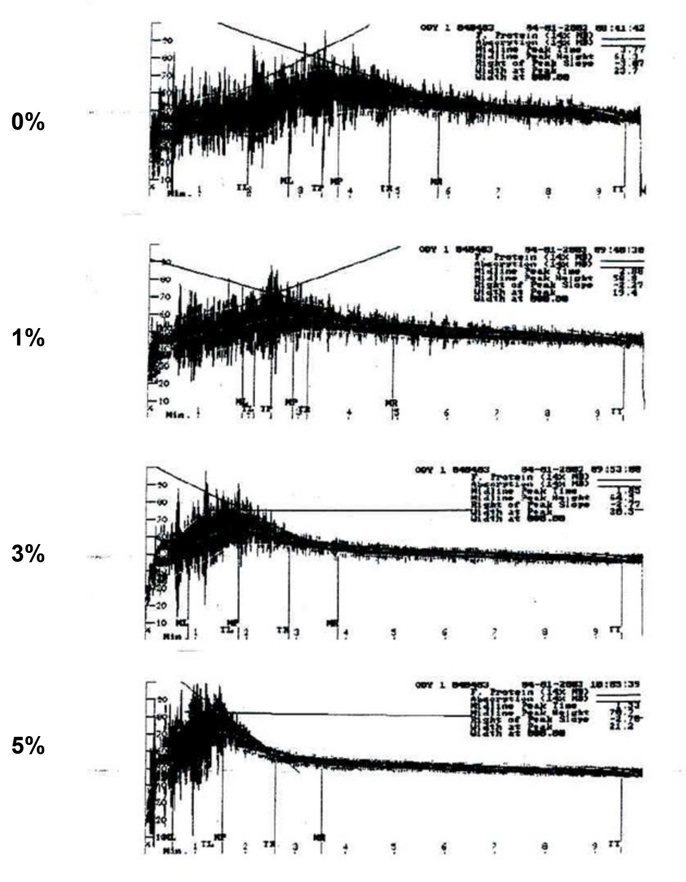


Fig. 7. Effects of adding 1%, 3% and 5% Arise® 6000 on the mixograph curves of wheat flour.

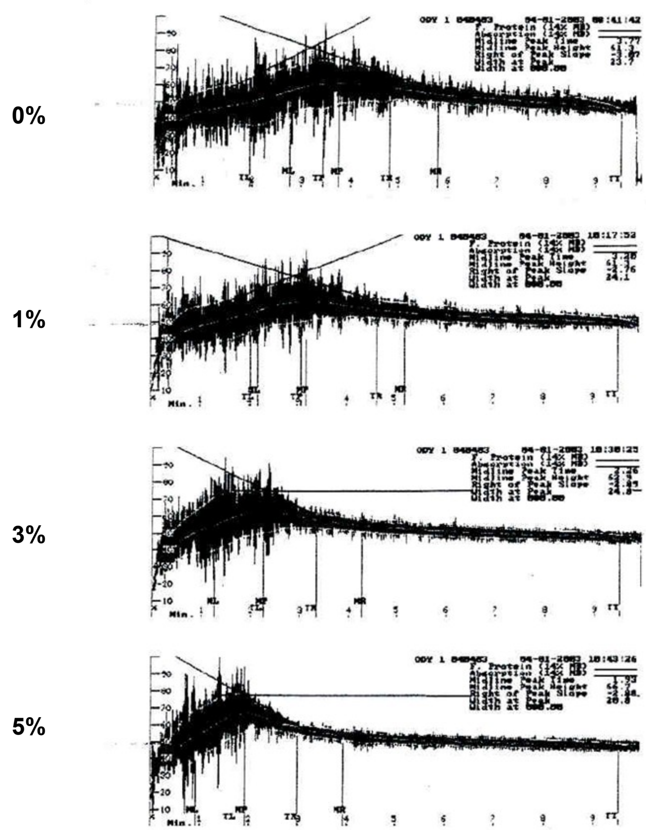


Table 3. Effects of wheat protein isolates and their level of addition on farinograph[a] quality of wheat flour.

Ingredients	Absorption, %	Peak Time, min.	Stability, min.	MTI, B.U.[b]
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]Farinograph analysis by AIB International
[b]MTI, B.U. = Mixing Tolerance Index, Brabender Units

Farinograph

Like the mixograph, a farinograph measures and records the resistance of a dough to mixing. A typical farinograph curve (farinogram) for wheat flour is illustrated in Fig. 9 (See Appendix C). Farinograph curves were run with wheat flour and also with 1.0%, 1.5% and 2.0% of Arise® 5000 or Arise® 6000 added to wheat flour. The results indicated that as the level of addition increased, water absorption also increased (Table 3). Farinogram stability decreases and Mixing Tolerance Index (MTI) increases with the addition of either Arise® ingredient. While the peak time tended to decrease with the addition of either Arise® 5000 or Arise® 6000, this was not directly related to the level of Arise® added. The preceding farinograph results are indicative of reducing action on the dough structure.

Four different production samples of Arise® 5000 at a 1.5% level of addition were compared for their effects on farinograph parameters of wheat flour. The data presented in Table 4 (see Appendix B) show that Arise® 5000 has the general effect of increasing water absorption, decreasing peak time (i.e. mixing time), decreasing stability and increasing MTI.

Extensograph

The extensograph (or extensigraph) records a force – time curve for a test piece of dough that is being stretched until it breaks. The appearance of the force – time curve (extensogram) is demonstrated in Fig. 10 (see Appendix C). Compared to the control (no additive) (14.4 cm), the extensibility of dough at a 45-minute rest period increased during the addition of 0.5% or 1.0% Arise® 5000 (15.5-17.3 cm) (Table 5).

Compared to the data at a 45-minute rest period, extensibility tended to decrease after 90 minutes (9.7-10.1 cm) and appeared to level off after 135 minutes (9.5-10.2 cm). It took a higher percentage addition (1.0-1.5%) for Arise® 6000 to elicit the same increase in extensibility (15.3-17.8 cm) at 45 minutes as Arise® 5000.

The dough at a 90-minute rest period had lesser extensibility (11.1 cm) compared to 45 minutes, but 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 values as the control (8.1 cm vs 8.3 cm), with 1.5% Arise® 6000 displaying an extensibility value of 9.4 cm. Overall, the general trend of the data in Table 5 (see below) indicates a stronger dough extensibility effect of 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 (Table 6).

Table 5. Extensibility at three resting periods of wheat flour with varying levels of Arise® 5000 and Arise® 6000 as determined in an extensograph.

	Extensibility, cm		
Additive	45 Minutes	90 Minutes	135 Minutes
No additive	14.4	9.3	8.1
0.5% Arise® 5000	15.5	9.7	9.5
1.0% Arise® 5000	17.3	10.1	10.2
1.0% Arise® 6000	15.3	11.1	8.3
1.5% Arise® 6000	17.8	11.1	9.4

Table 6. Resistance to extension of doughs with varying levels of Arise® 5000 and Arise® 6000 as measured by an extensograph.

	Resistance to Extension, BU[a]		
Additive	45 Minutes	90 Minutes	135 Minutes
Control	625	770	880
0.5% Arise® 5000	625	830	780
1.0% Arise® 5000	560	745	700
1.0% Arise® 6000	590	780	760
1.5% Arise® 6000	580	770	810

[a]BU = Brabender Units

In a separate experiment, Arise® 6000 was tested in the extensograph at 1%, 2% and 3% levels in wheat flour. The results show the general trend previously observed on the increase in dough extensibility (Table 7, see Appendix B), but a decrease in resistance to dough extension (Table 8, see Appendix B). Incorporation of higher levels (1%, 3% and 5%) of Arise® 5000 to wheat flour further confirmed the increase in dough extensibility (Table 9, see Appendix B) and the decrease in resistance to dough extension (Table 10, see Appendix B) as earlier noted.

Further extensograph data was accumulated by using Arise® 8000 as the protein additive to wheat flour. Compared to the control (no additive), the addition of 1%, 3% and 5% Arise® 8000 to wheat flour increased the resistance to extension of the dough after 45 minutes, 90 minutes and 135 minutes of rest period, respectively, although the effect was not linear (Table 11). Maximum resistance to extension was exhibited after a 90-minute rest period. The dough extensibility tended to decrease after 45-minute and 90-minute rest periods, but a 135-minute rest period either had no effect or slightly increased extensibility.

Table 11. Resistance to extension at three resting periods of wheat flour with varying levels of Arise® 8000 as determined in an extensograph

	Resistance to Extension, BU[a]		
Additive	**45 Minutes**	**90 Minutes**	**135 Minutes**
No additive	625	770	880
1% Arise® 8000	810	1000	930
3% Arise® 8000	765	1015	970
5% Arise® 8000	775	1030	1040

[a]BU = Brabender Units

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 alveograph curve for wheat flour is graphically recorded as shown in Fig. 11 (see Appendix C). When evaluated using an alveograph, Arise® 5000 has a stronger effect on increasing dough extensibility compared to Arise® 6000 (Table 12). For example, 0.5% Arise® 5000 has extensibility of 90 mm, whereas 1.0% to1.5% Arise® 6000 has extensibility of 87mm to 88 mm. In a separate experiment, higher levels (1%, 3% and 5%) of Arise® 5000 were evaluated for their effects on alveograph parameters. Table 13 shows (see Appendix B), dough extensibility generally increased and resistance to extension decreased, respectively, as the level of protein additive rose.

With respect to Arise® 8000, the resistance to dough extension was increased compared to the control (no additive), and the increase was apparently directly related to the level of Arise® 8000 (Table 14). Dough extensibility tended to decrease with the incorporation of Arise® 8000.

Table 12. Alveograph data of wheat flour with varying levels of Arise® 5000 and 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 14. Alveograph data of wheat flour with varying levels 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

Performance in Bakery and Other Food Products

White Pan Breads

The performance of Arise® 5000 and Arise® 6000 in white pan bread made using a sponge and dough process was evaluated using 1.0%, 1.5%, or 2.0% levels of addition based on flour (Table 15, see Appendix B). 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 16).

Table 16. Properties of sponge and dough process white pan breads formulated with varying levels of wheat protein isolates.

Treatment	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

Fig. 12. Effect of addition of 1% Arise® 6000 or 1% vital wheat gluten on dough mixing time of a whole wheat bread formula.

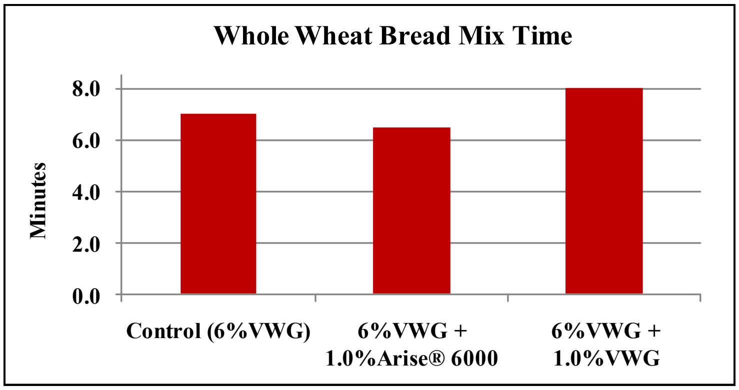
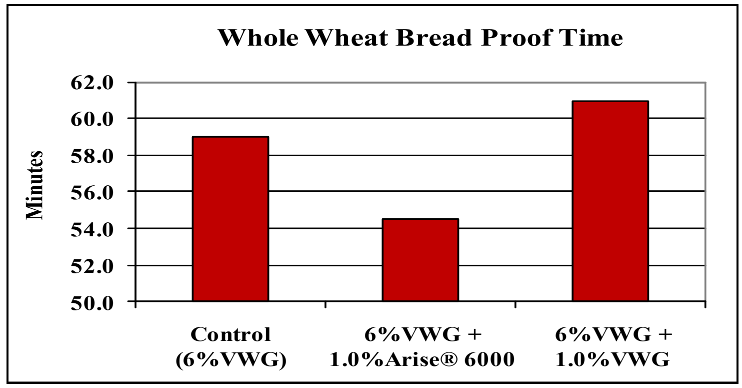


Fig. 13. Effect of addition of 1% Arise® 6000 or 1% vital wheat gluten on proof time of a whole wheat bread formula.



The specific volume of control 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 directly related to the level of addition.

Bread products re-heated in a microwave oven become soft immediately after heating, but developed a tough, rubbery or leathery texture upon cooling. It is believed that the toughness observed might have been caused by the interaction of adjacent gluten strands when the water was removed during microwave heating. The effect of wheat proteins on the microwave-induced toughness of pup loaf bread re-heated in a microwave oven is documented in a published university study. 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 additional 1% vital wheat gluten or 1% Arise® 6000 and all other ingredients remaining the same (Table 17, see Appendix B). When compared against the control whole wheat bread, Arise® 6000 decreased both dough mixing time (7.1%) and proof time (7.6%) (Figs. 12 and 13), whereas vital wheat gluten increased both parameters by 14.3% and 3.4%, respectively. Both protein products produced breads with larger loaf volumes (5.1%) compared to control bread.

High-Protein, High-Fiber Breads

A protein- and fiber-enriched whole wheat bread was formulated by incorporating high-protein (Arise® 5000 and vital wheat gluten) and high-fiber (Fibersym® RW and soy fiber) ingredients (Table 18, see Appendix B). Two bread formulas that used whole red wheat flour or whole white wheat flour containing the high protein and fiber ingredients exhibited softer crumbs (i.e., prolonged shelf-life) compared to control breads (Figs. 14 and 15).

Fig. 14. Change in crumb firmness during 10-day storage period of high-protein, high-fiber bread from whole red wheat flour with added Arise® 5000.

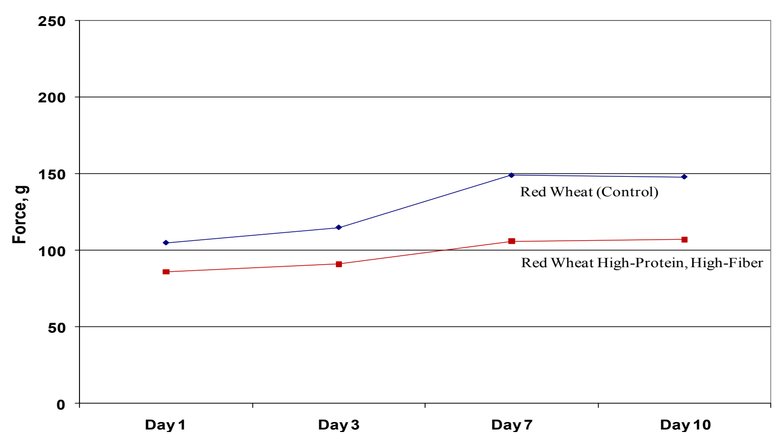
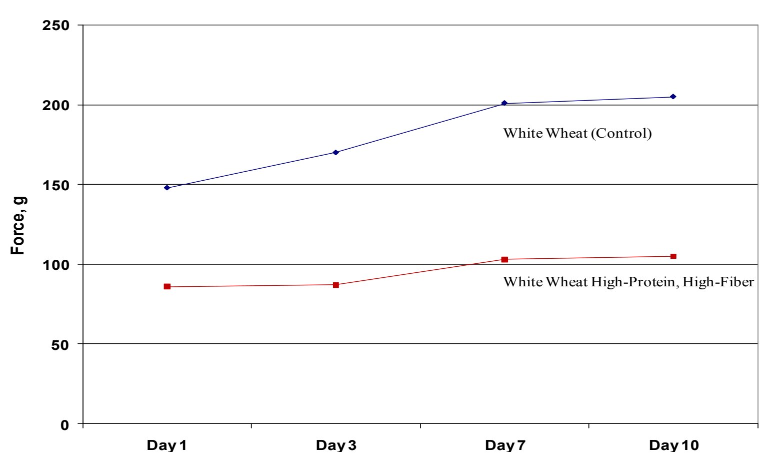


Fig. 15. Change in crumb firmness during 10-day storage period of high-protein, high fiber bread from whole white wheat flour with added Arise® 5000.



Flour Tortilla

Arise® 5000 was formulated in a flour tortilla formula at a level of 1% to 3% based on flour (Table 19, see Appendix B). Its incorporation had a positive effect on the shelf stability (Table 20) of the flour tortilla as shown by a significant increase in time (22-26 days) in which the tortilla had acceptable rollability scores compared to the control tortilla (10 days).

Table 20. Effects of Arise® 5000 on shelf stability of flour tortilla.

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

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 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

<u>Pasta</u>

Protein quantity and quality are the most important factors affecting pasta quality. The structure of the pasta dough consists of starch and other constituents enveloped by a three-dimensional protein network. The strength of this network impacts dough rheology and influences the behavior during processing, the rigidity of the pasta before, during, and after drying, and the 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 the semolina, the sample was blended for 15 minutes in a twin shell cross-flow dry blender, an appropriate amount of water (~31.5%) was added and mixed, and then processed on a DeMaco extruder fitted with a Teflon-coated die with a 0.157 cm opening to yield spaghetti strands. 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. 16). At 2% or 4% fortification level, Arise® 6000 showed a 28.1% and 78.3% increase, respectively, in firmness over the control. Addition of 2% and 4% egg white powder increased the firmness by 53.2% and 99.5%, respectively. The preceding data indicates that Arise® 6000 can be used as a cost-effective replacement for egg white powder in retorted pasta. Depending on the level of usage, ingredient savings can range from 21% to 41% (Fig. 17).

In a fiber-enhanced spaghetti (Table 21), Arise® 6000 added at a 12% level performed better than 12% vital wheat gluten because of the former's lower cooking loss and higher firmness exhibited by the cooked spaghetti. The fiber source in this formulation consisted of MGP's Fibersym® RW resistant wheat starch.

Fig. 16. Effects of 2% and 4% Arise® 6000 or egg white powder on firmness of retorted spaghetti.

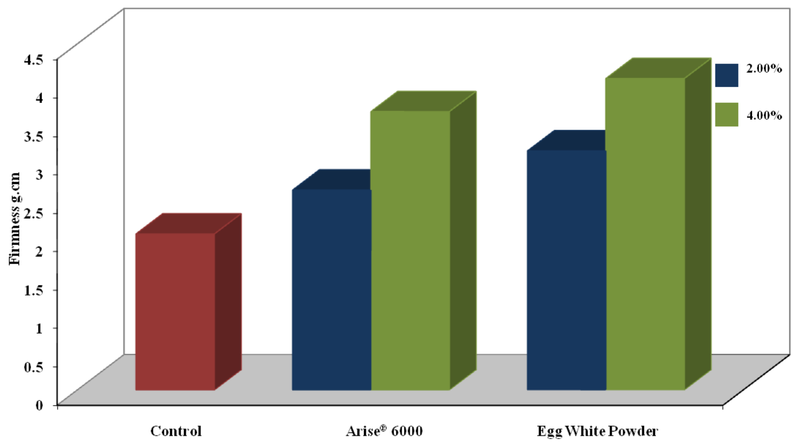


Fig. 17. Graphical presentation of calculated ingredient savings from the substitution of egg white powder with Arise® 6000 in retorted spaghetti.

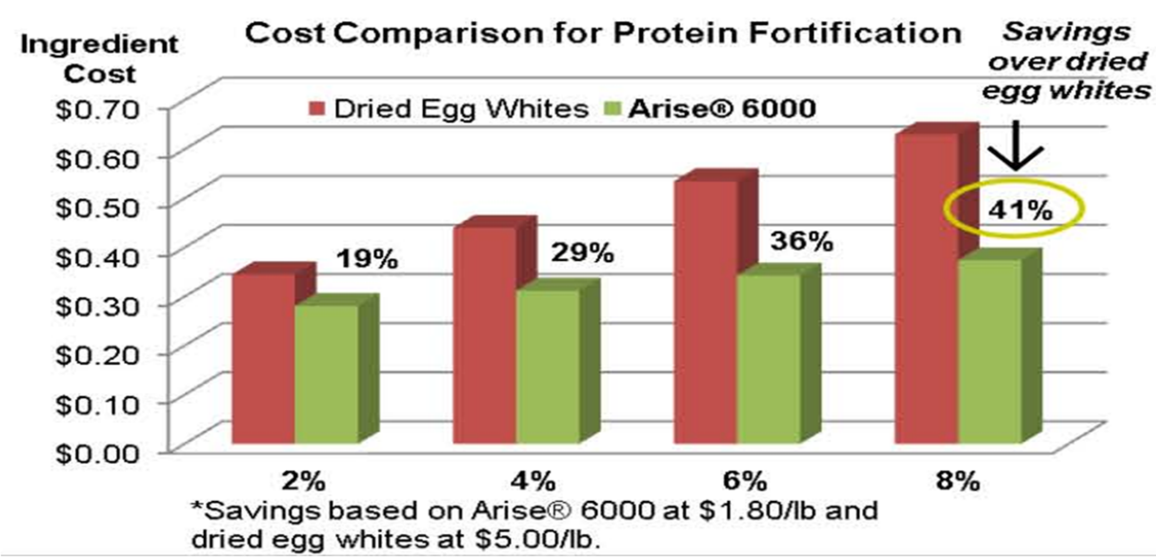


Table 21. Cooking properties of fiber-enhanced spaghetti with varying levels of vital wheat gluten or Arise® 6000 and Fibersym® RW.

Spaghetti Sample	Cooking Time, min.	Water Absorption, g/g	Cooking Loss, %	Firmness, gcm
100% Semolina	11.0	2.8	5.6	7.2
40% Semolina 12% Vital wheat gluten 48% Fibersym® RW	13.5	2.4	4.4	6.1
40% Semolina 12% Arise® 6000 48% Fibersym® RW	14.0	2.3	4.0	8.0

Noodles

Noodles are characterized by thin strips slit from sheeted doughs that have been made from wheat flour, water, common salt or alkaline salt. The types of noodles based on raw materials are wheat noodles (most Asian noodles), buckwheat noodles, starch noodles, and rice noodles. These 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 22-24, see Appendix B), were prepared in which the flour was replaced by 10% or 30% of a blend of Arise® 6000 and MGP's Fibersym® RW resistant wheat starch (16:84 ratio). After preparation, the noodles were photographed as shown in Figs. 18-20 (see below and right. 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 absorption 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 desired texture (bite, springiness, and mouthfeel) after cooking.

Fig. 18. Appearance of white salted noodles with 0% (Control), 10% and 30% substitution of the flour by a blend of Arise® 6000 and Fibersym® RW (16:84 ratio).

0% (Control) **10%** **30%**

Fig. 19. Appearance of chuka-men noodles with 0% (Control), 10% and 30% substitution of the flour by a blend of Arise® 6000 and Fibersym® RW (16:84 ratio).

0% (Control) **10%** **30%**

Fig. 20. Appearance of instant fried noodles with 0% (Control), 10% and 30% substitution of the flour by a blend of Arise® 6000 and Fibersym® RW (16:84 ratio).

0% (Control)

10%

30%

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 25). 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 26). With instant fried noodles, 2% of Arise® 5000 and Arise® 6000 have comparable, but better texture scores than Arise® 8000, vital wheat gluten or the control sample (Table 27).

Table 25. Effects of vital wheat gluten and protein isolates on texture of 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 26. Effects of vital whet gluten and wheat protein isolates on texture of 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 27. Influence of vital wheat gluten and wheat protein isolates on instant fried noodle texture.

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

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 and 4% salt (Table 28, see Appendix B). The ingredients in commercial predust formula B consisted of 92.5% all-purpose flour, 5% egg white powder, 2% salt and 0.5% baking powder (Table 29, see Appendix B. 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 in 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 375ºF. 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, the percent adhesion using commercial predust formula A was as good and even slightly better for the two wheat protein isolates (Table 30). Commercial predust formula B yielded similar adhesion performance between egg white powder and the two wheat protein isolates (Table 31). 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.

Table 30. Egg white replacements 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 31. Egg white replacements 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

The 75% level of egg white replacement appears to give the best adhesion scores for Arise® 5000 and Arise® 6000 in both commercial predust formulas (Tables 30 and 31). 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.

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 30). 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 31).

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. Both Arise® 5000 and Arise® 6000 performed satisfactorily as egg white replacers at 50% to75% substitution levels in two commercial predust formulas for coated chicken fingers.

Appendix A

The Following is a Listing of Related Publications and Patents on Wheat Proteins and Their Specialty Versions:

1. Maningat, C.C., Nie, L., Bassi, S.D., Kelley, G.A., and Trompeter, E.E. 2011. Wheat protein isolates and their modified forms and methods of making. European Patent 1758461 B1.

2. Elmusa, A.A., Morris, C.A., and Willis, H.L. 2009. Egg replacement and emulsifier system and related methods. U.S. Patent Application Pub. No. U.S. 2009/0041901 A1.

3. Maningat, C. C., Bassi, S. D., Ranjan, S., Gaul, J. A., Stempien, G. J., Dohl, C. T., and Woo, K. 2008. High-protein, reduced-carbohydrate bakery and other food products. Australian Patent No. 2004253169.

4. Bassi, N.D., Bell, L.R., Carson, B.A., Germain, N., and Giroux, M. 2008. Wheat protein and methods of production. U.S. Patent Application Pub. No. U.S. 2008/0254200 A1.

5. Ledbetter, K.R. and Werstak, C.E. 2008. Compositions comprising wheat protein isolate and related methods. U.S. Patent Application Pub. No. US 2008/0181990 A1.

6. Borders, C.K., Carson, B.A., Egbert, W.R., McEver, M.E., and Schaefer, M.J. 2007. Protein isolate compositions and uses thereof. U.S. Patent Application Pub. No. U.S. 2007/0014914 A1.

7. Gaul, J.A., Dohl, C.T., Stempien, G.J., Maningat, C.C., and Bassi, S.D. 2005. Reduced fat absorption in prepared foods. U.S. Patent Application Pub. No. U.S. 2005/0031753 A1.

8. Maningat, C., Bassi, S., Woo, K., Dohl, C., Gaul, J., Stempien, G., and Moore, T. 2005. Formulation of high-protein, high-fiber (low-carbohydrate), reduced calorie breads. AIB Tech. Bull. 27(4):1-16.

9. Pascut, S., Kelecki, N., and Waniska, R.D. 2004. Effects of wheat protein fractions on flour tortilla quality. Cereal Chem. 81:38-43

10. Miller, R.A., Maningat, C.C., and Bassi, S.D. 2003. Effect of gluten fractions in reducing microwave-induced toughness of bread and buns. Cereal Fds. World 48:76-77.

11. Hoseney, R. C., Miller, R. A., Bassi, S., and Maningat, C. C. 2002. Microwaveable bread products. U. S. Patent 6,482,454.

12. Maningat, C. C. and Bassi, S. 1997. Specialty products. In Wheat Gluten – More Than Just Bread, PBI Bulletin (September issue), p. 6-7.

13. Maningat, C. C. and Bassi, S. 1997. Wheat gluten and specialty wheat gluten products. In Proceedings of Expanding Agriculture Co-Product Uses in Aquaculture Feeds (December 5-7, 1994), Des Moines, IA, p. 130-162.

14. Maningat, C. C., Bassi, S., and Hesser, J. M. 1994. Wheat gluten in food and non-food systems. *AIB Tech. Bull*. 16(6):1-8.

Appendix B

Table 2. Effects of protein additives on mixograph quality of three wheat flours.

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
3% Arise® 6000	2.5	5.0

Adapted from Pascut et al 2004

[a]Mixograph Units

Table 4. Influence of four production samples of Arise® 5000 (1.5% level) on farinograph[a] quality of wheat flour.

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

Table 7. Extensibility of doughs with varying levels of Arise® 6000 as measured by an extensograph.

	Extensibility, cm		
	45 Minutes	90 Minutes	135 Minutes
Control	18.9	17.6	16.8
1% Arise® 6000	25.2	18.6	17.6
2% Arise® 6000	22.9	18.5	17.9
3% Arise® 6000	19.7	18.9	15.3

Table 8. Resistance to extension of doughs with varying levels of Arise® 6000 as determined in an extensograph.

	Resistance to Extension, BU[a]		
	45 Minutes	90 Min-utes	135 Minutes
Control	787	1022	1190
1% Arise® 6000	776	1003	1113
2% Arise® 6000	722	947	1053
3% Arise® 6000	673	1019	1028

[a]BU = Brabender Units

Table 9. Extensibility of doughs with varying levels of Arise® 5000 as measured by an extensograph.

	Extensibility, cm		
	45 Minutes	90 Minutes	135 Minutes
Control	14.4	9.3	8.1
1% Arise® 5000	16.2	16.2	13.0
3% Arise® 5000	17.2	14.0	12.6
5% Arise® 5000	203	15.2	13.6

Table 10. Resistance to extension of doughs with varying levels of Arise® 5000 as determined by an extensograph.

	Resistance to Extension, BU[a]		
	45 Minutes	90 Minutes	135 Minutes
Control	625	770	880
1% Arise® 5000	580	680	620
3% Arise® 5000	470	700	650
5% Arise® 5000	440	530	495

[a]BU = Brabender Units

Table 13. Alveograph data of wheat flour with varying levels of Arise® 5000.

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

Table 15. Sponge and dough white pan bread process formulas[a] with different levels 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 18. Whole wheat bread formulas[a] containing high protein and high fiber contents.

	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 monoglycerides	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]Forumlas = Expressed in Baker's Percent

Table 17. Whole wheat bread formulas[a] for evaluating the effects of protein additives on bread quality.

	Control	**Vital Wheat Gluten**	**Arise® 6000**
Ingredients	Baker's Percent		
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	0
Arise® 6000	0	0	1.0
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]Forumlas = Expressed in Baker's Percent

Table 19. Formulation of flour tortilla containing 1%, 2% or 3% 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 22. Formulas of control white salted noodles and those containing blends of Fibersym® RW and Arise® 6000.

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

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 24. Formulas for control instant fried noodles and those containing blends of Fibersym® RW and Arise® 6000.

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 28. Composition (%) of control commercial predust formula A and those containing Arise® 5000 or Arise® 6000 to replace 50%, 75% and 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 29. Composition (%) of control commercial predust formula B and those containing Arise® 5000 or Arise® 6000 to replace 50%, 75% and 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 C

Fig. 5. Typical appearance of a mixograph curve of wheat flour.

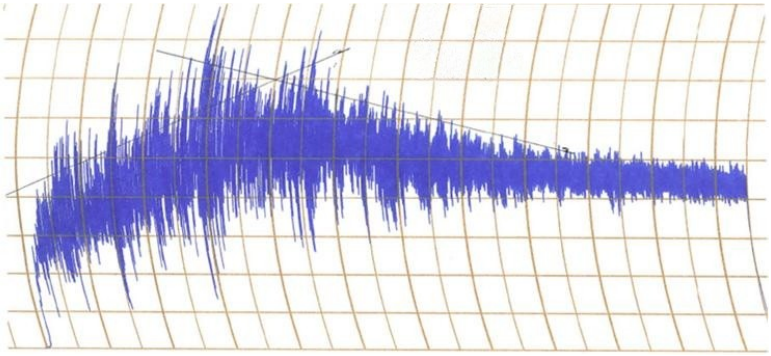


Fig. 8. Effects on mixograph curves of wheat flour after adding 1%, 3% and 5% vital wheat gluten.

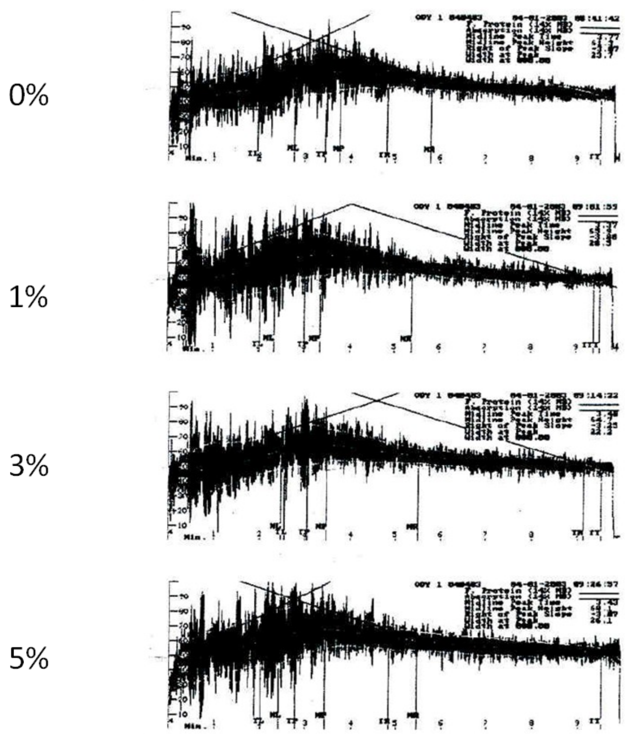


Fig. 9. Typical mixing curve of wheat flour as measured in a farinograph.

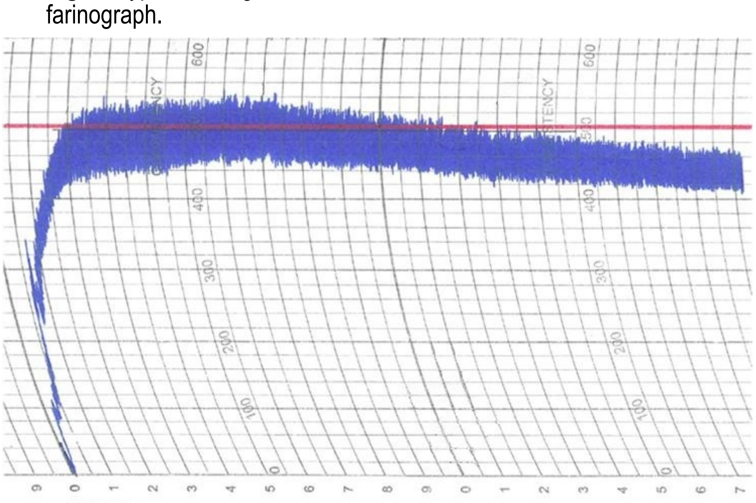


Fig. 10. Typical appearance of extensograph curves of wheat flour as measured in an extensograph.

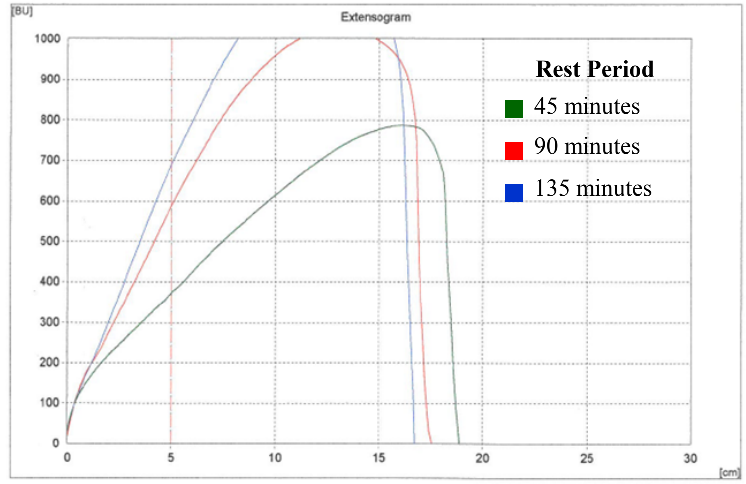
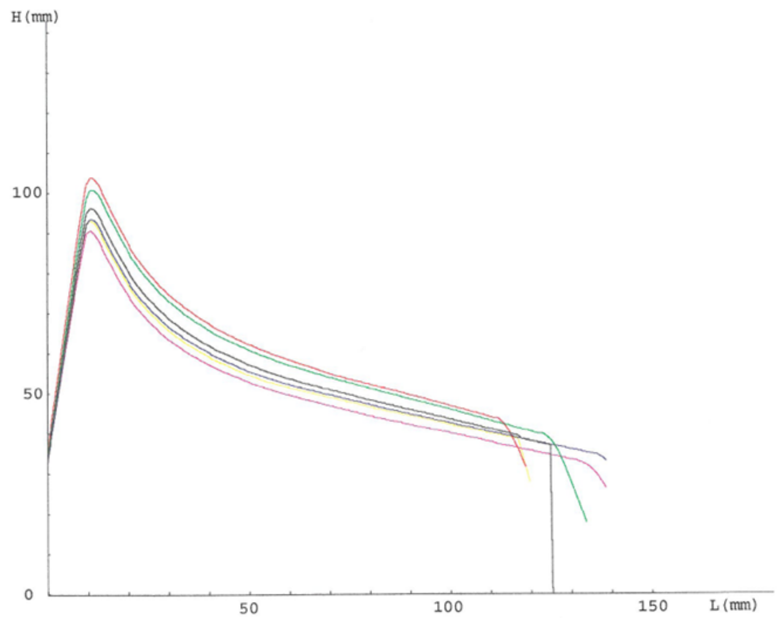


Fig. 11. Graphical representation of the alveograph curves of wheat flour (six measurements).



CREATING BETTER SOLUTIONS...NATURALLY

Headquartered at:
Cray Business Plaza
100 Commercial Street
P.O. Box 130
Atchison, KS 66002

866.547.2122
www.mgpingredients.com

Listed on the NASDAQ Global Select Market
and traded under the symbol MGPI.