FEATURE

Properties and Applications of Texturized Wheat Gluten

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The International Grains Council estimates that the 1999 world wheat production will reach 568.8 million tons, down from the 583.4 million tons and 610.1 million tons harvested in 1998 and 1997, respectively (1). Wheat has a predominant role (2) in the grain trade and is utilized as food (67%), feed (20%), seed (7%), and industrial products (6%). Judging from the 1997 estimated worldwide gluten production of 825 million pounds (3), only a small portion of harvested wheat is used for the manufacture of wheat starch and wheat gluten. A somewhat higher annual estimate of 1.1 billion pounds of world gluten production was reported by Weegels (4). Approximately 23% of the 1997 estimated amount of gluten is produced in North America. The top eight gluten producing countries in descending order are France, United States, Australia, Netherlands, Germany, United Kingdom, Belgium, and Canada (5).

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Wheat gluten and wheat starch are economically important coproducts produced during wet processing of wheat flour (5–7). Both products and their derivatives have multiple uses in the food and industrial sectors (7,8). Wheat gluten is a commodity food ingredient, and its applications are predominantly in baked goods, breakfast cereal, pet foods, and processed meat products (9,10). In the past few years, there have been growing signs that gluten is being transformed into a market-driven, value-added product (11,12). Evidencing this transformation is the market proliferation of specialty protein products derived from wheat gluten, such as texturized wheat gluten, wheat protein isolate, wheat gliadin, wheat glutenin, hydrolyzed wheat protein, glutamine peptides, and deamidated wheat gluten (6, 13–20). These specialty wheat proteins are finding increasing uses in nontraditional gluten markets as calf milk replacers, cosmetics, egg white replacers, pasta, biscuits, dairy products, nutritional drinks, energy bars, processed meat products, and vegetarian foods.

Texturization of Proteins

The texturized vegetable-protein market has traditionally been based on soybeans (21–23). The principal raw materials used are either soy flour, soy protein concentrate, or soy protein isolate. Major uses of texturized proteins are in meat extension and vegetarian products. Processes for texturization involve spinning (24,25), jet cooking (26), steam texturizing (27), and extrusion cooking (28–30). Among these processes, extrusion has been the preferred technology. While texturized wheat gluten can be considered a newcomer to the scene, its functionality and unique fibrous

structure have made a major impact in many food applications.

The patent literature (31–36) describes several processes for developing the fibrous structure of texturized wheat gluten to simulate meat fibers (Table I). These processes involve chemical, mechanical, thermal, extrusion, or a combination of treatments. In close resemblance to texturized soy proteins, the texturized wheat gluten currently on the market is also produced by extrusion technology (13–17).

During extrusion, wheat gluten is subjected to a continuous thermomechanical treatment, leading to mixing, hydration, shear, compression, temperature rise, pressure build-up, pasteurization, stream alignment, shaping, expansion, and partial drying (37). Within the extruder barrel, the materials are heated to form a hot viscous mass called protein lava (38). As the protein lava is conveyed to the terminal portion of the extruder, variables such as temperature, pressure, moisture, and die assembly are carefully controlled to ensure proper texture and fiber development. The lava is discharged from the die without excessive water flash-off in order to avoid cell disruption. The result is a product that has a visible, oriented pattern of fiber arrangement that resembles meat fibers, especially after it is soaked 30 min in water (Fig. 1). Alignment of wheat protein molecules during the extrusion process results in the formation of thin filaments or microfibrils, which assemble further to form a macroscopic fibrous structure. Hydration of the fibrous strands gives the laminated, fleshy appearance of texturized wheat gluten.

Properties of Texturized Wheat Gluten

Texturized wheat gluten is available commercially in several forms differing in size, shape, bulk density, color, texture, hydration rate, and hydration capacity. Sizes can vary from ground form to chunks, and it can appear in the form of coarse powder, bits, flakes, granules, flat chips, or cubical/cylindrical chunks. In its natural, hydrated form, texturized wheat gluten exhibits a fibrous texture resembling chicken meat while the caramel or malt-colored product mimics beef meat. Bulk density is dependent on size and shape of the product and varies from 10 to 18 lb/ft^3. The hydration rate ranges from 15 to 45 min and is dependent on product dimension and water temperature. Texturized wheat gluten absorbs water to about 2.5–4 times its weight. Examination of the hydrated product reveals strong and elastic fiber components that assemble into bundles. Table II depicts the typical properties of different types of texturized wheat gluten. Hydrated texturized wheat gluten is reported to contain 18.8% protein, 2.35% carbohydrate, 1.05% fat, and 0.47% dietary fiber (16). The reported benefits of texturized wheat gluten are its low fat content; fibrous texture; chewability; neutral flavor; cost-effectiveness; adaptable size, shape, and color; good nutritional balance; and the ease with which it can be stored (15,16).

Use in Meat Extension

In meat products, the numerous benefits that can be achieved from using plain, vital wheat gluten as a binder, filler, or extender (Table III) are well documented (39–52). At a level of 1–5%, wheat gluten acting as a binder in restructured meats imparts several benefits, such as increased viscoelasticity, color stability, firmness, juiciness, and moisture retention (39–42). Fat binding and cooking loss are also reduced (42). In other meat pieces and processed meat products, the binding ability of wheat gluten at 1–13% level contributes to high yield, low cooking loss, better adhesion, increased structural strength, good rehydration properties, better sliceability, and retention of sensory attributes (43–47). As a filler or extender in processed meat products, wheat gluten incorporated at a level of 3–80% increases yield, improves cook stability, enhances firmness, improves product stability, and retains product texture (48–52).

After texturization, its applications in the food industry range from extenders of processed meat products to nutritional bars to vegetarian products. Extension of meat products has been practiced for many years, and ingredients used for extension include hydrocolloids/gums, starches, and texturized vegetable proteins. Texturized wheat gluten, which when chopped into flakes absorbs three times its weight in water, has been successfully incorporated into burgers, curry, chili con carne, chicken kievs, and nuggets (17). For example, chicken nuggets can be extended with 30% hydrated texturized wheat gluten (Table IV). Using texturized gluten in meat extension can provide cost savings of 12–26%, increased product yields of 8–9%, and improved texture of the finished product. The neutral flavor profile of texturized wheat gluten also helps reduce the production cost of extended meat products as additional flavoring or spices are not needed to mask any nonmeat flavors. Texturized wheat gluten resembles the appearance of meat fibers, thus enhancing prod-

Table I. Processes for Developing Meatlike Fibrous Structure of Wheat Gluten

Process	Materials	Product Characteristics	References
Chemical/mixing/heating	Wheat gluten + $NaHCO_3$ + $NaHSO_3$ + citric acid + NaCl	Fibrous structure	31
Chemical/mixing	Wheat gluten + Na_2SO_3	Netlike, fibrous structure with strong binding property	32
Chemical/mixing	Wheat gluten + organic acid + ascorbic acid	Netlike, fibrous structure with strong binding property	33
Mixing/shredding/heating	Wheat gluten + wheat flour + yeast	Loose layered, textured fiber-strand structure	34
Extrusion/stretching/heating	Wheat gluten + meat + starch	Continuous fiber structure	35
Extrusion	Wheat gluten + wheat flour + flavoring	Fibrous structure	36

Table II. Typical Properties of Different Types of Texturized Wheat Gluten

Type	Moisture	Protein (d.b.)	Water Absorption (g/g)
Coarse powder	4.3%	65.5%	2.7
Flakes	4.6%	68.4%	3.0
Chips	8.3%	60.1%	2.6
Expanded chips	8.4%	66.7%	3.2
Cylindrical chunks	5.3%	66.1%	3.4

Fig. 1. Hydrated texturized wheat gluten showing meatlike fibrous texture.

uct integrity, texture, and mouthfeel. Another practical application is as a hamburger extender; up to 40% of hydrated texturized wheat gluten can be used in precooked and uncooked patties.

Use in Vegetarian Foods

Meatless meals have been listed as one of the top food trends for the 21st century (53), and the increasing number of vegetarians is helping to propel this trend. The term "vegetarian," however, is ambiguous because it designates so many diets, such as vegan, ovo-vegetarian, lacto-vegetarian, ovo-lacto vegetarian, pollo-vegetarian, pesco-vegetarian, semivegetarian, and fruitarian (54,55). Determining the size of the vegetarian population in the United States is difficult because of this variety of practices and attitudes. For instance, about 1–2% of the U.S. population are considered strict vegetarians, yet when asked whether or not they are vegetarians, approximately 7% of the population claim to have a vegetarian diet. As much as 26% of the population is vegetarian-aware, meaning that, while they are not necessarily vegetarians, they are cutting back on meat consumption and looking for vegetarian foods at restaurants or supermarkets. Forty percent of the population is cutting back on consumption of red meat by substituting it with poultry and fish and may occasionally seek vegetarian meals as an alternative.

In a published survey quoted by Otto (56), consumers report that they became vegetarians out of concern for health (46%), animal welfare (15%), or the envi-

Table III. Benefits of Wheat Gluten as a Binder, Filler, or Extender in Meat Products

Use	Level	Meat Product	Benefits	References
Extender/binder	3.6%	Restructured beef steak	Viscoelastic texture	39
Binder	2%	Restructured beef steak	Better color stability	40
Binder	1–2%	Restructured chicken steak	Increased firmness, enhanced juiciness	41
Binder	2–5%	Restructured chicken steak	Increased moisture retention, less fat binding, decreased cooking loss	42
Binder	0.8 g/25.8 cm²	Restructured pork block	Enhanced viscoelasticity	43
Binder	1.5%	Chicken pieces	High adhesion properties, low cooking loss, high yield	44
Binder	0.1g/cm²	Meat pieces	High binding ability	45
Binder	0.10–0.15%	Pork sausage and meatballs	Structural strength, good rehydration properties	46
Binder/water absorption	3–13%	Meat loaf	Comparable sensory properties, better sliceability	47
Extender	3.5%	Frankfurter	Comparable texture	48
Extender	5–20%	Wiener	Comparable cooking profile and yield, comparable texture	49
Filler	6.8%	Wiener	Improved product stability, increased yield, increased firmness	50
Extender	20–80%	Meat emulsion	Increased yield, improved cook stability	51
Extender	3.5%	Meat batter	Comparable stability and texture	52

Table IV. Products Incorporating Hydrated Texturized Wheat Gluten

Product	Form of Texturized Wheat Gluten	Typical Levels
Chicken nugget	Hydrated chips	30%
Hamburger patties		
precooked	Hydrated flakes	20–40%
uncooked	Hydrated coarse powder	20–40%
Vegetarian chicken nuggets	Chips	29%
Vegetarian Italian sausage	Flakes	29%
Vegetarian chicken salad	Chunks	12%
Vegetarian crab cake	Hydrated chips	76%
Vegetarian pork barbecue	Hydrated chips	46%

Table V. Incorporating Texturized Wheat Gluten in a Granola Bar Recipe

Ingredients	Amount
Corn syrup	18.5%
Texturized wheat gluten (flakes)	15.0%
Wheat protein isolate	3.0%
Chocolate coating	15.0%
Date paste	5.0%
Granola	8.7%
Crisp rice	7.0%
Honey	10.0%
Chocolate chips	10.0%
Coconut	1.5%
Almonds	1.5%
Brown sugar	4.7%
Nutmeg	0.1%
Total	100.0%

ronment (4%) or owing to the influence of family and friends (12%) or ethical reasons (5%) or they report that they are not sure/other (18%). The development of vegetarian food has also been fueled by product innovation (57). On the other hand, the decline in popularity of red meat can be attributed to anxiety about mad cow disease, the growing concern for animal welfare, the move towards healthier diets, the need for dietary change, and boredom (15). The market for vegetarian alternatives to meat and dairy products in 1999 has been estimated to be $662 million (53).

The use of wheat gluten in vegetarian foods is not new. Seitan, the wheat gluten-based meat substitute, has been around for years and was popular in the early Mormon community (58). It has been a staple food among the vegetarian monks from China, the wheat farmers from Russia, and the peasants of Southeast Asia. The cohesive and elastic character of wheat gluten is the basis for many simulated meat products where it holds ingredients and provides chewy texture.

A variety of vegetarian food products can be formulated with texturized wheat gluten, such as vegetarian chicken nuggets, sausage, chicken salad, crab cake, and pork barbecue (Table IV). In addition to contributing to structure, it mimics meat's texture, chewability, and appearance and also helps in providing the needed protein for a healthy diet. It can be mixed, chopped, or ground to achieve a fibrous texture, yielding a meatlike appearance. It is also used as a low-cost ingredient that can replace more expensive ingredients, thus lowering the overall finished-product cost.

Use in Nutritional Products

Today, people are looking for healthy snacks or foods that can provide a boost of energy or help build muscle. The energy or protein bar industry has been gaining momentum over the last few years for this very reason. Texturized wheat gluten can be used in these formulations, such as in those for granola-type nutritional bars, as illustrated in Table V. This bar provides essential vitamins, minerals, and protein. Along with adding protein fortification, texturized wheat gluten imparts a crunchy texture to the bar. The neutral flavor of texturized wheat gluten also provides economic benefits for energy bar producers because little flavoring is needed to produce these snacks.

Opportunities and Challenges

There are a multitude of applications for texturized vegetable proteins in the food industry. Texturized wheat gluten is finding uses in existing traditional markets and, being a relatively new product, has experienced steady growth. New markets being tested for uses of texturized wheat gluten include breakfast cereals, bakery products, snack foods, and microwaveable products.

In addition to providing a concentrated source of protein, texturized wheat gluten offers unique textural benefits. Retort stability is important in canned foods and pet foods. In order to further enhance its utilization, texturized wheat gluten needs to possess the physical, chemical, and textural properties necessary for withstanding the rigors of modern-day food processing. To achieve these properties, the formulation and processing variables could be altered, or the wheat gluten could be coextruded with proteins from oilseeds, legumes, milk, and other cereal proteins. This would improve nutritional properties and could enhance functionality. It remains to be seen how texturized wheat gluten will be used in food applications in the future.

References

1. World wheat crop in '99–00 to fall as export trade rebounds. Milling and Baking News 78(6):23, 1999.
2. Oleson, B. T. World wheat production, utilization, and trade. In: *Wheat: Production, Properties, and Quality.* W. Bushuk and V. F. Rasper, Eds. Chapman & Hall, New York, 1994.
3. *Functional and Modified Proteins—Markets and Applications Towards 2005.* L. Hepner and Associates, London, 1998.
4. Weegels, P. L. Wheat gluten: market, applications, and opportunities. Industrial Proteins 3:5, 1996.
5. Maningat, C. C., and Bassi, S. D. Wheat starch production. In: *International Starch Technology Conference.* M. Tumbleson, P. Yang, and S. Eckhoff, Eds. University of Illinois, Urbana, IL, 1999.
6. Maningat, C. C., and Seib, P. A. Update on wheat starch and its uses. In: *Proceedings of International Wheat Quality Conference.* J. L. Steele and O. K. Chung, Eds. Grain Industry Alliance, Manhattan, KS, 1997.
7. Maningat, C. C., Seib, P. A., Bassi, S. D., and Lasater, G. D. Wheat starch: Production, Properties, Modification, and Uses. In: *Starch Chemistry and Technology.* 3rd ed. R. L. Whistler and J. N. BeMiller, Eds., in press.
8. Bietz, J. A., and Lookhart, G. L. Properties and non-food potential of gluten. Cereal Foods World 41: 376, 1996.
9. Maningat, C. C., Bassi, S. D., and Hesser, J. M. Wheat gluten in food and nonfood systems. AIB Tech. Bull. 16:1, 1994.
10. Lens, J.-P., Mulder, W. J., and Kolster, P. Modification of wheat gluten for nonfood applications. Cereal Foods World 44:5, 1999.
11. After the storm: Domestic wheat gluten industry begins long road to recovery. Milling and Baking News. p. 1, Dec. 1, 1998.
12. Specialty wheat products sow functionality. Food Prod. Design. p.117, Jan. 1999.
13. Maningat, C. C., and Bassi, S. D. Wheat gluten and specialty wheat gluten products. In: *Workshop Proceedings—Expanding Agriculture Co-Product Uses in Aquaculture Feeds.* The Midwest Feeds Consortium, Des Moines, IA, 1994.
14. Maningat, C. C., and Bassi, S. D. Specialty products. PBI Bull. Nat. Res. Council Canada, Saskatoon, Saskatchewan, September 1997.
15. Wheat meat. Food Processing 60:9, 1991.
16. New vegetable protein developed. Int. Food Ingredients 6:22, 1991.
17. Murray, N. Eureka. Frozen & Chilled Foods 46:38, 1992.
18. Friedli, G. L., and Howell, N. Gelation properties of deamidated soluble wheat proteins. Food Hydrocoll.10:255,1996.
19. Steijns, J. Dietary proteins as the source of new health promoting bio-active peptides with special attention to glutamine peptide. Food Tech Europe 3(1):80, 1996.
20. Hyprol in sports food and drinks. World of Ingredients p.44, Jan./Feb. 1996.
21. Hansen, L. P. *Vegetable Protein Processing.* Noyes Data Corp., Pea Ridge, NJ, 1974.
22. Gutcho, M. H. *Textured Protein Products.* Noyes Data Corp., Pea Ridge, NJ, 1977.
23. Smith, A. K., and Circle, S. J. *Soybeans: Chemistry and Technology.* AVI Publishing Co., Westport, CT, 1978.
24. Horan, F. E. Soy protein products and their production. J. Am. Oil Chem. Soc. 51:67A, 1974.
25. Rosenfield, D., and Hartman, W. E. Spun-fiber textured products. J. Am. Oil Chem. Soc. 51:91A, 1974.
26. Wilcke, H. L., Waggle, D. H., and Kolar, C. K. Textural contribution of vegetable protein products. J. Am. Oil Chem. Soc. 56:259, 1979.
27. Strommer, P. K., and Beck, C. I. Texturization by passage through elongated pipe in presence of steam at elevated pressure and temperature. U.S. patent 3,754,926, 1973.
28. Noguchi, A. Extrusion cooking of high-moisture protein foods. In: *Extrusion Cooking.* C. Mercier, P. Linko, and J. M. Harper, Eds., American Association of Cereal Chemists, St. Paul, MN, 1989.
29. Stanley, D. W. Protein reactions during extrusion processing. In: *Extrusion Cooking.* C. Mercier, P. Linko, and J. M. Harper, Eds. American Association of Cereal Chemists, St. Paul, MN, 1989.
30. Harper, J. M. *Extrusion of Foods.* vol. II. CRC Press, Inc., Boca Raton, FL, 1981.
31. Muroi, C., Ogawa, G., and Inuzuka, S. Process for the manufacture of meat-like wheat gluten products. Canadian patent 848,913, 1970.
32. Shemer, M. Novel physical form of gluten, method for its manufacturing, and its uses. U.S. patent 4,238,515, 1980.
33. Shemer, M. Gluten possessing a fibrous

structure, its manufacture, and meat-like products obtained thereby. U.S. patent 4,938,976, 1990.
34. Huber, C., and Longo, N. Method of making vital wheat gluten into fibers. U.S. patent 5,593,717, 1997.
35. Yoshioka, T., Yamamoto, T., Nishiyama, T., Fujita, H., and Ashida, S. Process for preparing foodstuff having fiber restructure. U.S. patent 4,615,901, 1986.
36. Barnes, O. J., and Stone, A. P. Improvements in and relating to textured wheat gluten protein products. WO 96/36242, 1996.
37. Cheftel, J. C. New protein texturization processes by extrusion cooking at high moisture levels. Food Reviews Intl. 8:235, 1992.
38. Crocco, S. C. Better texture for vegetable protein foods. Food Eng. Intl. 1(9):16, 1976.
39. Hand, L. W., Crenwelge, C. H., and Terrell, R. N. Effects of wheat gluten, soy isolate, and flavorings on properties of restructured beef steaks. J. Food Sci. 46:1004, 1981.
40. Chen, C. M., and Trout, G. R. Color and its stability in restructured beef steaks during frozen storage: Effects of various binders. J. Food Sci. 56:1461, 1991.
41. Seideman, S. C., Durland, P. R., Quenzer, N. M., and Carlson, C. W. Effect of added wheat gluten and mixing time on physical and sensory properties of spent fowl restructured steaks. J. Food Protection 45:297, 1982.
42. Seideman, S. C., Durland, P. R., Quenzer, N. M., and Carlson, C. W. Utilization of spent fowl muscle in the manufacture of restructured steaks. Poultry Sci. 61:1087, 1982.
43. Terrell, R. N., Crenwelge, C. H., Dutson, T. R., and Smith, C. G. A technique to measure binding properties of non-meat proteins in muscle-juncture formation. J. Food Sci. 47:711, 1982.
44. Baker, R. C., Darfler, J. M., and Vadehra, D. V. Prebrowned fried chicken 2. Evaluation of predust materials. Poultry Sci. 51:1220, 1972.
45. Siegel, D. G., Church, K. E., and Schmidt, G. R. Gel structure of nonmeat proteins as related to their ability to bind meat pieces. J. Food Sci. 44:1276, 1979.
46. Ranadive, A. S., Huang, E. A., and Seltzer, E. Storage stability and rehydrability of comminuted, lyophilized, and compressed meat products. J. Food Sci. 41:1122, 1976.
47. Thomas, M. A., Turner, A. D., and Hyde, K. A. Meat loaf type canned products based on milk or plant proteins. J. Food Technol. 11:51, 1976.
48. Keeton, J. T., Foegeding, E. A., and Patana-Anake, C. A comparison of nonmeat proteins, sodium tripolyphosphate, and processing temperature effects on physical and sensory properties of frankfurters. J. Food Sci. 49:1462, 1984.
49. Ma, C.-Y., Yiu, S. H., and Khanzada, G. Rheological and structural properties of wiener-type products substituted with vital wheat gluten. J. Food Sci. 56:228, 1991.
50. Comer, F. W., Chew, N., and Lovelock, L. Comminuted meat products: Functional and microstructural effects of fillers and meat ingredients. Can. Inst. Food Sci. Technol. 19:68, 1986.
51. Randall, C. J., Raymond, D. P., and Voisey, P. W. Effect of various animal and vegetable protein materials on replacing the beef component in a meat emulsion system. J. Inst. Can. Sci. Technol. Aliment. 9:216, 1976.
52. Patana-Anake, C., and Foegeding, E. A. Rheological and stability transitions in meat batters containing soy protein concentrate and vital wheat gluten. J. Food Sci. 50:160, 1985.
53. Brown, J. A. The good news about vegetarian foods. Whole Foods 20(5):36, 1997.
54. Meister, K. *Vegetarianism.* American Council on Science and Health, New York, NY, 1997.
55. Kobs, L. A vegetarian vision. Food Product Design 9:37, 1999.
56. Otto, A. The new vegetarian: Meatless goes mainstream. Food Business 5(22):10, 1992.
57. Palmer, C. Taking the meat out of the meal. Food Manufacture 72(9):21, 1997.
58. Breuninger, H. Seitan poised for industry growth. Natural Foods Merchandiser. 15:62, 1994.

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