free of the glucosinolates (Table V). The glucosinolate extraction process is increased by the employment of weak NaOH solution or polar solvents such as methanol, ethanol, or acetone. The diffusion method can reduce the relatively high losses of nitrogen substances which are soluble in water. In the process of obtaining rapeseed protein isolates, the glucosinolates and products of their degradation are removed in the protein precipitation process, together with the wastewater.

The partial reduction in levels of the glucosinolates, isothiocyanates and vinyloxazolidinethiones in the extracted meal can be obtained by toasting, but deleterious protein changes occur during toasting which would preclude using intense heat to produce food protein products.

The antitryptic agents particularly active in the pulse seeds, are much less active in rapeseed (Table VI). This protein is highly sensitive to the effect of temperature and is effectively destroyed during toasting.

The hemagglutinins with glycoprotein structures occur both in the soybean and in the rapeseed in similar, small quantitites, and their presence in the finished product is not a critical problem from a nutritional point of view.

REFERENCES

1. Kozlowska, H., and R. Zadernowski, Zesz. Nauk. ART Olszt. Tech. (In press).
2. Rutkowski, A., N. Barylko-Pikielna, H. Kozlowska, J. Borowski, and L. Zawadzka, "Evaluation of Soybean Protein Isolates and Concentrates as Meat Additives to Provide a Basis for Increasing Utilization of Soybeans," USDA-ARS Grant No. 13, Final Research Report, Olsztyn, 1977.
3. Cichoń, R., H. Kozlowska, B. Lossow, and O.B. Smith, 5th International Rapeseed Conference, Malmo, Sweden, 1978.
4. Korolczuk, J., and A. Rutkowski, JAOCS 48:398 (1971).
5. Soral-Smietana, M., H. Kozlowska, and Z. Borejszo, Roczn. Nauk. Roln. 103:182 (1978).
6. Kozlowska, H., H. Nowak, and R. Zadernowski, Zesz. Nauk. ART Olsztyn-Tech. 11:132 (1977).
7. Kloczko, J., and A. Rutkowski, Acta Alim. Pol. (In press).
8. Kozlowska, H., R. Zadernowski, H. Nowak, and J. Przystalski, Przemysl Spozyw. (In press).
9. Rotkiewicz, D., H. Kozlowska, and L. Światek, Hodowla, Rosl. Aklim. Nasienn 20:447 (1976).
10. Kozlowska, H., D. Rotkiewicz, and Z. Borejszo, Zesz. Nauk ART Olszt. Tech. 11:123 (1977).
11. Kozlowska, H., M.A. Sabir, and F.W. Sosulski, Can. Inst. Food Sci. Technol. 8:160 (1975).
12. Kozlowska, H., K. Elkowicz, and B. Lossow, Unpublished Data.
13. Kozlowska, H., J. Borowski, and K. Elkowicz, Zesz, Nauk ART Olszt. Tech. 10:47 (1976).

Wheat Gluten Applications in Food Products

F. KALIN, Industrial Grain Products, PO Box 6089, Montreal, Quebec, Canada

ABSTRACT

Vital wheat gluten has traditionally been noted for its functional benefits in various bakery applications. In recent years extensive research and development work has taken place to more clearly identify wheat gluten's unique characteristics and functional properties. As a result, many new and novel applications have been developed. The on-going potential of this exciting protein ingredient, in its native or modified forms, will only be limited by the imagination of those formulating new products.

INTRODUCTION

The major use of vital wheat gluten to date has been in bakery applications, where it has contributed to dough strength; gas retention and rise; improvements in texture, rigidity and bite in the finished products; flavor improvement; hinge strength in buns and rolls; and increased water absorption.

Many flour millers have used vital wheat gluten to streamline production. Instead of milling usually expensive wheat blends to meet bakery flour standards, lower cost local wheats can often be used with wheat gluten supplementation to satisfy functionality requirements. In recent years the unique properties of this protein ingredient have been utilized in various other food formulations.

WHEAT GLUTEN PROPERTIES

The natural properties of vital wheat gluten may be broadly summarized as physical and structural uniqueness; complementary nutrition; and complementary flavor and color.

Physical and Structural Uniqueness

Table I shows a typical analysis of vital wheat gluten.

Native wheat gluten fractionates into two different classes of proteins: gliadin and glutenin (Figure 1.). Hydrated gliadin is an extensible syrupy material, whereas hydrated glutenin is a cohesive and rubbery mass. Together they make wheat gluten "vital" and "alive," unlike other natural plant proteins. This vitality in hydrated gluten is clearly illustrated in the following structural and functional proerties.

Ability to form a visco-elastic mass. With a certain amount of mixing, hydrated gluten develops into a firm, resilient, and adhesive substance, insolube in water and exhibiting both plastic and elastic properties.

Ability to form films. When the formed visco-elastic mass is further mixed, it develops into a continuous three-dimensional webwork of films. Solid particles as well as gas bubbles may, thus, be enveloped throughout this continuous gluten mass.

Thermosetting ability. When heated above 85 C, the hydrated gluten mass coagulates irreversibly and without loss of its unique structural order, yielding a firm, nonsticky, moist, clean cutting and resilient gel.

In practice, these gluten properties play important roles. Once hydrated, gluten's visco-elastic character provides a structural basis on which a food system may be built. Its adhesive and film-forming property binds the system's particulate matter (e.g., starches, meat tissues, fat globules). Its thermosetting attributes upon cooking entrap and bind together the originally discrete particles and help retain moisture and gases evolved. Finally, the firm, moist, clean cutting, and resilient character of cooked gluten films contributes to end product quality.

TABLE I

Typical Analyses of Vital Wheat Gluten

Protein N x 5.7, dry basis, (d.b.)	75.0%-80.0%
Moisture	5.0%- 8.0%
Ether extractable fat, d.b.	0.5%- 1.5%
Ash d.b.	0.8%- 1.2%
Water absorption capacity	150%- 200%

GLUTEN

(Differential solubility in alcohols)

Soluble gliadin	Insoluble glutenin
- Intramolecular bonds	- Intra and intermolecular bonds
- Low molecular weight (< 100,000)	- High molecular weight - (> 100,000)
- Highly extensible	- Less extensible
- Less elastic	- Highly elastic

FIG. 1. Fractionation of native wheat gluten.

TABLE II

Essential Amino Acid Content of Typical Cereals and Oilseeds (1,2)

Amino acid	Amino Acid Content (mg/g protein) WHO/FAO Pattern (1973)	Wheat	Maize	Soybean
Lysine	55	31	27	70
Threonine	40	31	36	42
Methionine and cystine	35	43	35	28
Leucine	70	72	125	85
Isoleucine	40	35	37	50
Valine	50	47	48	53
Phenylalanine and tyrosine	60	81	87	89
Tryptophan	10	11	7	14

Complementary Nutrition

Wheat gluten has a protein content of 75% to 80% (N x 5.7, d.b.). In formulations where a protein conversion factor of 6.25 is used, wheat gluten attains a calculated protein equivalent of 82% to 88%, just short of an "isolate" classification. As a typical cereal grain product, wheat gluten is limiting in lysine. Its protein efficiency ratio (PER) is between 0.7 and 1.0, against casein control at 2.5. Table II lists the essential amino acid content of wheat in comparison to maize and soybean.

However, wheat gluten is comparatively rich in the sulfo-amino acids, methionine, and cystine. Because most oilseed proteins, such as the soybean, as well as proteins from beef, pork and casein, are deficient in sulfo-amino acids but rich in lysine, blends with wheat gluten will improve the over-all PER through synergism (Table III).

Complementary Flavor and Color

Wheat has been, and continues to be, one of the most widely consumed cereals in the world, and its flavor is well accepted. Assuming reasonable processing care, the extracted gluten tends to be bland in flavor, with a mild cereal note.

The color of most wheat glutens is light tan; variations may result from different drying techniques and particle size distributions. Recent advances in production technology can provide a wheat gluten which is near-white.

APPLICATIONS

Bakery Products

The use of vital wheat gluten in baking is a widely researched and documented subject. Those gluten properties responsible for successful baking include: (a) visco-elastic properties for dough strength, especially in variety breads; (b) film-forming ability for gas and moisture retention to ensure proper configuration, volume and texture; (c) thermosetting properties for structural rigidity to provide needed bite characteristics; (d) water absorption and retention capacity for product softness, to extend shelf-life and to reduce baking costs; (e) gluten's natural flavor enhances consumer acceptability of baked goods.

TABLE III

Protein Efficiency Ratio (PER) of Wheat Protein/Soy Protein Blends, Relative to Casein PER of 2.5 (3)

	Wheat Protein to Soy Protein Blend Ratio 100:0	55:45	45:55	30:70	0:100
PER	0.8	2.1	2.3	2.4	2.0

Private study, John Labatt Limited, London, Ontario, Canada, 1975.

Much research and development work has been focused on the production of composite flours. Vital wheat gluten could play a major role in optimizing the use of native carbohydrates into efficient bakery raw materials. Banana, breadfruit, millet, casava, maize, and others are being investigated.

Meat, Fish and Poultry Products

The unique adhesive and film-forming character of hydrated vital wheat gluten and its thermosetting properties are largely responsible for its use in these products.

When allowed to hydrate and develop fully, gluten forms a continuous three-dimensional webwork of films that holds together the pieces of meat, fish, or poultry. These pieces may be flaked slivers or fist-sized chunks. After cooking, gluten's thermosetting properties bind the pieces into an integral whole. The resilience, bite, and texture of cooked gluten closely resembles the physical properties of meat, fish, and poultry.

Actual applications range from extended ground meats, fabricated steaks, canned "integral" hams and turkey rolls, through wieners and bolognas, to fish and meat sausages, pizza toppings, meat pies, and others.

The natural properties of gluten obviate the need for thermal-extrusion, except for convenience in handling in some applications. Blends of textured soy and powdered gluten perform satisfactorily.

The pet food industry uses vital wheat gluten in many canned luxury products to replace meat. The flavor of wheat gluten is totally acceptable to pets, even when used at exaggerated levels.

Pasta

In pasta products, added gluten permits the use of lower strength regional flours. For normal pasta, added gluten also contributes to such end product qualities as improved bite, reduced loss on cooking, more tolerance to over-cooking and improved canning and retort stability. The trend toward nutritionally fortified pasta products with soy and other ingredients generally requires makeup gluten to compensate for the dilution effect and loss of physical properties. Since the time between pasta dough formation and extrusion is generally short, rapid reconstitution or fast acting glutens are required to ensure attainment of full functionality.

Breakfast Cereals, Breading and Batter Mixes

Flavor, as well as adhesive and textural properties, have contributed to gluten use in cereals, breading, and batter mixes. In batter mixes gluten not only forms a film to encase the essential juices, but itself bakes to a crisp, appetizing surface crust. Cereals benefit from gluten's binding and ashesive properties, desirable flavor and color, as well as nutritional synergism to milk, with which cereals are commonly consumed.

Aquaculture

In aquaculture vital wheat gluten holds fish feed ingredients together, making them more stable in water. This contributes to feeding efficiency, reduced pollution and disease, and helps minimize drain on oxygen. The fact that wheat gluten is a high protein ingredient also greatly complements feed formulations.

Nutritional Snacks

Wheat gluten is used in many nutritional snack items. Examples include the Australian varieties of high protein (30% to 45%) wafers, Japanese Fu Cakes, European "gluten ball" products, and Chinese fried gluten entrées.

THE HIGHLY ADAPTABLE INGREDIENT

In recent years extensive research and application studies have indicated that wheat gluten may be chemically and physically modified to provide specific functional properties. For some years wheat glutens capable of accelerated rehydration rates and able to assume full functionality in a fraction of the regular time requirements have been commercially available. These were developed to satisfy ever-increasing mass production speeds. Where ease of handling and dispersibility in liquid systems are important, modified wheat gluten products are available. These modifications do not detract from the unique functional character of native gluten. "Deferred vitality" products and those treated with emulsifiers and other dispersing agents are important examples.

In certain meat, fish, and cheese extension work, it becomes desirable to deemphasize bite and magnify extensibility. This is achieved by chemically, or enzymatically, disrupting intermolecular bonds.

Wheat gluten may be rendered partially or totally soluble via acidic or enzymatic treatments. Whippable glutens could thus be produced and, when the reaction is continued further, glutens could be rendered soluble and, hence, functional in nutritious beverages. Thermal treatment renders wheat gluten nonfunctional, without detracting from its flavor or nutritive value. Devitalized products handle and disperse as any other plant protein would. The major end use points are in hydrolyzed vegetable proteins, nutritional biscuits, cookies and snacks, and as biological substrates in fermentation work.

SUMMARY

In general, identifying and selling food products as extenders, imitations, substitutes, health panaceas and so on, with the prime objective being "cheapness," is not compatible with normal consumer motivations to buy. It is believed that, regardless of the current economic state of any society, the people within it still regard eating as an experience related to a quality of life tied to cultural, traditional, or family backgrounds, rather than as a means of survival alone.

Within the consumer-oriented marketing approach, the formulation of new protein-based food products should consider, in order of importance, appearance, taste or flavor, organoleptic properties, nutrition and, last but not least, costs. With this approach the mortality rates of new product introductions should be considerably reduced.

Finally, new, plant, protein-based product development should consider improving on today's range of food products, rather than attempting to duplicate them with alternate raw materials. There are no perfect foods today, so that research spent on duplicating current products can only be justified as an intermediate step toward the more Utopian foods of tomorrow. These will probably be a marriage of several and many complementary proteins and compatible additives from diverse sources, optimizing on the functionality attributes of each and, hopefully, utilizing locally available cereals, oilseeds, pulses and so on, under economically sound conditions. As suggested by many, a worthwhile objective would be the formulation of foods where meats would be considered the extender. To this end, wheat gluten could play a major role.

REFERENCES

1. Amino Acid Content of Foods and Biological Data on Proteins, FAO Publication 24 (1970).
2. Hulse, J.H., and E.M. Laing, "Nutritive Value of Triticale Protein," Monograph IDRC-021e, Canada, 1974.
3. John Labatt Limited, London, Ontario, Canada, 1975, Private study.

Food Applications of Corn Germ Protein Products

G.E. INGLETT and **C.W. BLESSIN**, Northern Regional Research Center, SEA/ARS/USDA, Peoria, IL USA

ABSTRACT

Many convenience foods such as meat analogs, breakfast foods, and baked goods use ingredients prepared from cereal grains and their processed products. Among the most important new cereal protein products, corn germ protein products appear to have the greatest potential food markets.

CORN PROTEINS

Corn, also called maize, is the number one cereal in U.S. agriculture. In 1976, 6.22 billion bu. were produced having a farm value of $14.4 billion (1). Approximately 10% of the corn crop in the United States is processed by wet milling, dry milling, and distilling industries (2). About 10% of the whole corn kernels consists of proteins. More than 75% of these proteins are contained in endosperm tissue (Table I). The embryo is twice as high in protein as the endosperm (19% vs. 9%), but it is only 10% of the kernel. Four classes of corn proteins are known based on their solubility: albumins (water soluble), globulins (saline solution soluble), prolamine (70% ethanol soluble), and glutelin (soluble in 0.1*M* NaOH). Most of the protein in the corn embryo consists of albumins and globulins, which are less than 10% of the protein in the endosperm (3).

Proteins have been prepared from whole corn or from dry or wet milled fractions. A large source of protein is available from this grain. One such product is corn germ flour.

Defatted Corn Germ Flour From Dry Milled Fractions

The commercial germ fraction from corn dry milling