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.

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Food Applications of Corn Germ Protein Products

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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

TABLE I

Protein Distribution in Corn and Corn Fractions (3)

Component	Whole grain, %	Endosperm, %	Germ, %	Bran and tip cap, %
Kernel	100	84	10	6
Kernel protein	100	76	20	4
Protein in fraction	10	9	19	5
Part protein:				
Albumins	8	4	30	---
Globulins	9	4	30	---
Zein	39	47	5	---
Glutelin	40	39	25	---

TABLE II

Composition of Corn Germ Flour (4)

Constituent	Percent[a]
Protein	25.3
Lysine	1.49
Methionine	0.54
Tryptophan	0.35
Fiber	4.2
Starch	24.7
Sugars	13.8
Pentosans	11.7
Fat	0.5
Ash	10.3
Phosphorus	2.74
Potassium	2.36
Magnesium	1.02
Calcium	0.015
Sodium	0.014
Iron	0.020

[a]Moisture-free basis.

contains fragments of bran, grits, and tip cap. Additional screening provides an enhanced embryo-rich material suitable for more processing. Germ streams were separated into +6, -6+10, and -10 mesh fractions. Aspirated +6 and -6+10 fractions were combined, flaked, extracted with hexane, and ground to flour. The finished flour consisted of material passing through a 9XX silk (4,5). Preliminary examination of the composition of this flour shows a protein content of 25% with the remaining parts being composed of starch, sugars, pentosans, fiber, vitamins, and minerals (Table II).

Dry milled germ fractions from yellow, white, and high

TABLE III

Proximate Analyses of Defatted Corn Germ Flours (6)

Germ flour	Constituent, %[a]			
	Fat	Ash	Fiber	Protein
Yellow	1.1	11.0	4.0	25.2
Yellow	0.3	11.6	3.3	23.1
Yellow	0.5	10.4	5.1	23.0
White	0.8	7.8	5.6	20.5
White	1.0	10.1	4.9	23.7
High lysine	0.5	11.6	5.1	22.3

[a]Moisture-free basis.

lysine corns from different mills were then evaluated to sources of food-grade high-protein flours (6). Yield and compositional data on fat, ash, fiber, and protein were obtained on all the fractions. Protein content of the finished flours ranged from 20 to 25% (Table III). Amino acid compositions of the protein in the flours were similar regardless of corn type or mill source. Lysine accounted for ca. 5% of the 17 recovered amino acids. Very little difference was found in the contents of threonine, glutamic acid, proline, methionine, and lysine in the yellow, white, and high lysine germ flour (Table IV) (6).

The nutritional value of corn germ flour prepared commercially from yellow dent corn was found to be essentially equivalent to casein by PER measurement (7). Corn germ flour was also an excellent source of protein for meeting maintenance requirements of rats (8). Its relative protein value also indicated that corn germ flour contains good quality protein (9).

Defatted corn germ flour was evaluated in cookies, muffins, and beef patties, and the compositional changes in starch, fat, protein, ash, and fiber were measured for these food products with various amounts of the added germ flour (10). Defatted corn germ flour was also used as a nutrient fortifier in bread by Tsen et al. (11). Protein-fortified cookies were prepared by Tsen (12) using various composite flours. Oatmeal cookies fortified with defatted corn germ flour at 12, 24, and 36% levels (no wheat flour basis) were found to have improved taste, flavor, and texture.

Flour from Wet Milled Corn Germ

A flour containing 30% protein with 5.9% lysine and a good balance of other essential amino acids was prepared from wet milled corn germ (13). To prepare the flour, dried wet mill corn germ was first aspirated to remove hull and,

TABLE IV

Amino Acid Composition of the Protein in Germ Flours from Yellow, White, and High-Lysine Corn[a]

Amino acid	Yellow			White		High lysine
	Mill 1	Mill 2	Mill 3	Mill 4	Mill 5	Mill 6
	Finished flour	Finished flour	Finished flour	Finished flour	Finished flour	Finished flour
Aspartic acid	9.1	8.9	8.7	9.1	8.9	9.9
Threonin	4.1	4.0	4.0	4.1	4.1	4.0
Serine	5.5	5.5	5.6	5.6	5.8	5.9
Glutamic acid	13.9	14.8	14.6	15.7	15.2	14.7
Proline	6.4	6.0	6.2	7.6	6.3	5.2
Glycine	6.4	6.3	6.3	5.7	5.9	6.4
Alanine	6.9	6.6	7.1	7.1	6.8	6.7
Cystine	1.8	2.1	1.8	1.7	1.7	1.4
Valine	5.0	6.3	6.4	4.9	6.1	6.5
Methionine	2.4	2.3	2.1	1.9	2.0	2.0
Isoleucine	3.6	3.4	3.5	3.5	3.7	3.5
Leucine	7.6	7.7	8.1	8.7	8.5	7.4
Tyrosine	3.8	3.5	3.8	3.9	3.9	3.6
Phenylalanine	4.9	4.6	4.8	4.7	5.0	4.8
Histidine	3.0	3.2	2.8	2.8	2.5	2.9
Lysine	5.9	5.4	5.4	4.8	5.0	4.7
Arginine	9.6	9.3	8.8	8.2	8.6	10.5

[a]Percent of recovered amino acid.

after flaking, lipid was removed by solvent extraction. Very low lipid levels were achieved in the final product by a second extraction of the flakes with 82:18 hexane/ethanol azeotrope via refluxing. The ground flour contains ca. 2% ash, 18% starch, and 0.6% lignin. The flour also contains large amounts of dietary fiber (22-29% pentosans and 11-13% cellulose). Work is underway to evaluate the value of this product in foods.

Corn Germ Isolate

Corn germ protein isolate containing 73% or higher protein was obtained by processing the defatted dry milled germ. An alkaline extraction of this germ meal at pH 8.7 extracted 50% of the total nitrogen (14). Acid precipitation of the extract gave a product containing more than 73% protein. The total lipid and free lipid was considerably reduced by extraction with 80% ethanol, which gave a product with better flavor and storage stability.

Zein

Past, present, and potential uses of zein were reviewed by Reiners et al. (3). Zein sales are small but continue to look promising for increased usage in food coatings, particularly for candy and tablet coatings.

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Food Applications of Oat, Sorghum, and Triticale Protein Products

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ABSTRACT

Oat, sorghum, and triticale protein products offer considerable potential as food supplements. Each has special characteristics applicable to improved food product development. High protein or high lysine lines of these grains have been developed in recent years. Oat, sorghum, and triticale protein fractions have been separated from their grains by wet and dry milling procedures and also by air classification. Recent research is reviewed here concerning production and applications of the protein products.

OAT PROTEIN PRODUCTS

Oats, the fourth largest cereal crop in the United States and the fifth largest in the world, are an important feed grain for livestock and poultry in the temperate regions of the world. They contain good quality protein, an excellent amino acid profile, and can have a high protein content (15-22%). Up to now only a small, though significant, part of the crop has been used for human consumption, mainly as rolled oat groats (a breakfast food), or oat flour. Because oats are nutritionally better than other cereal grains, their potential as a protein additive source is great.

During the past 10 years, through governmental and university breeding programs, new strains of high protein oats have been developed. Several high protein cultivars are now in production and are being planted by farmers. Oats may be considered to be a high protein type when the groat contains more than 18% on an "as is" basis. Current interest in nutrition has made purchasers of oat grain highly conscious of its protein content.

Preparation

Increased attention has been directed in recent years toward development of methods for production of protein concentrates and isolates from oats. Several promising methods have been reported but have not as yet been adopted industrially. These processes involve aqueous wet milling fractionation of the groat flour complex, a mechanical separation of flour components by air classification, and separation of the protein fraction from the oat flour in aqueous and nonaqueous media.

Wet milling: The wet milling process, a nonconventional method, was developed for producing oat protein concentrate, starch, and residue fractions from oat groats having moderate and high protein contents (1). The optimum yield of protein was obtained in dilute alkali solution at pH 10 (2). The protein was isoelectrically precipitated, centrifuged, and isolated. The process yields three main products (protein concentrate, starch, and gum), all of which offer much food and nonfood industrial application potential. Concentrates prepared by this method have a good amino acid profile and good nitrogen solubility around pH 2.5 and above 8 (3). One outstanding property of the concentrate is its bland flavor. It also possesses reasonable hydration capacity and emulsion stability.

Air classification: Protein concentrates from oat flour and oat groats have also been produced by an air classification method (4). Flours and defatted oat groats were finely ground and air classified to yield fractions with proteins ranging from 4-88%. A unique fraction (83-88% protein) comprising 2-5% weight, accounted for 14, 16, and 7%, respectively, of the total protein in first and second flours and groats. Although small in quantity, this fraction is significant in that it is almost pure protein. Since high protein varieties give the best air classification response, recent and continuing genetic improvements in protein level of oats add even further significance.

Air classification results and analytical data on the fractions from the oat flours and ground oats indicate that oat protein concentrate with good amino acid composition can be produced at low cost. Further refinement of the air classification procedure to optimize the process may