

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

increase the yield of high protein fractions and make oat protein concentrate still more economical. In comparison to wet milling, the whole process is simpler and not as costly.

Other methods: Protein fractions of 50-57% have been reported separated from oat flour and bran by direct centrifugation (12,000 x g) of a water slurry (flour-water, 1:3) (5). In addition to a protein-rich layer, starch, residue bran, and water-soluble layers were present. Residue bran containing 16-19% protein and the starch fraction would be useful by-products from the fractionation. This method would offer an economical source of oat protein for food supplement use, since the protein layer could be air dried at controlled temperatures, thus eliminating any expensive freeze-drying techniques.

Another procedure for separating protein and carbohydrate from oat flour has recently been described (6). The fractions were separated on the basis of density using nonaqueous (fluorocarbons) solvent systems. Fractions with over 70% protein content were separated; however, they represent only about 40% of the protein available in the flour. The starch fraction retained 10% protein, with approximately half the flour protein remaining in this fraction.

Oat Protein Products: Properties and Applications

Oats are an excellent food source because their protein is high in nutritional quality with a good balance of essential amino acids. There is not much difference in amino acid composition between the groats and the protein concentrates. A high protein variety, for example, Garland, has excellent lysine and total sulfur amino acids per 16 g nitrogen and has a good amino acid distribution. PER values, corrected to standard casein set at 2.5, amounted to 1.9 for a high protein oat cultivar and 1.8 for the protein concentrate from it. Evidently, any processing involved in preparing protein concentrates does not decrease their nutritional value. The high protein lines are also high in oil (7-8%), but high oil content can cause difficulties in storage. Oat protein concentrate has good nitrogen solubility around pH 2.5 and above 8 and has reasonable hydration capacity and emulsion stability. The leading, most promising characteristic of oat protein is its bland flavor.

The water-soluble gum fraction, a by-product in the wet milling groat fractionation, has considerable potential value in food uses. The gum fraction, 5% of the weight of the groat flour, contains ca. 15% protein. Experimental food preparations have been made in which the gum fraction was substituted for standard ingredients in various recipes; for example, oat gum was used as a replacement for the eggs in a sugar cookie recipe. A tasty crisp cookie resulted. Other food and nonfood uses of the gum fraction include its use as a food thickener, an ice cream stabilizer, a substitute for other plant gums, a textile size, as well as its medicinal uses.

Limited application of oat concentrates in food and beverages has chiefly been due to nonavailability of the product. However, work has appeared on oat protein concentrates for beverage fortification (2). Neutral or acidic beverages were fortified with up to 4% oat protein concentrates. Milk-like and breakfast type beverages containing nutritious oat protein could be easily prepared and flavored. Some oat isolates have been reported to have attractive water-binding capacity, good emulsifying activity, and good emulsion stability. These properties suggest possible use as fat emulsifiers and water-absorbing agents in prepared foods. The residue after one protein extraction in the wet milling process was successfully extruded to a crispy snack food item. A possible breakfast cereal type product could be envisioned using the extruded protein-containing residue.

It is reasonable to say that oat protein concentrates offer food use possibilities comparable to those of soybean (7). Experimental use has been made of oat concentrates as meat extenders and as supplements in baked goods. The fact that oat protein concentrate possesses high nutritive value, bland taste, suitable solubilities, and potential for adequate production capacity to keep demands supplied is a suitable reason for continuing research and development of this high potential product.

SORGHUM PROTEIN PRODUCTS

In many semiarid regions of the world, calorie deficiency, especially in times of drought, is the most important nutritional problems. Grain sorghum, because of its great tolerance to drought and high yield capacity, is a major crop in such areas. Although the grain is grown primarily as a source of calories (it usually contains only 10% protein), it is still a primary provider of protein in such regions because of its extensive consumption in foods.

In Asia and Africa, 90% of the sorghum grain is directly consumed by humans and may provide up to 50% of the dietary protein. In contrast, in the United States most of the 700-million-bushel annual production is used as animal feed; but several dry milling operations process grain for food, beverage, and industrial uses. The poor nutritional quality of sorghum grain protein has necessitated that it be supplemented with oilseed meals such as soy to provide adequate nutrition (8). Recent discoveries of high lysine sorghum lines (9) have encouraged breeding of a grain that can make a better contribution to protein quality requirements of man and nonruminant livestock. Protein-rich products from sorghum grain are therefore of considerable interest for food products.

Dry Milled Products

The major use of sorghum is as a ground or milled product, although the whole kernel can be pearled or roasted. Most native cultures grind the whole grain to prepare meal for gruels or chappatis. In developed countries, modern technologies are used to dry mill sorghum and to separate germ and hull from ground endosperm. Sorghum may be roller milled, as is wheat, or dehulled like rice prior to grinding (10). More than 70% of the grain of the normal sorghum can be converted into grits, but the soft, high lysine grain yielded much more flour and less grits (11). The germ fraction had the highest protein and lysine contents of fractions from both grains. The flour portion had the highest lysine content of the endosperm-derived fractions, but the lysine content of all products from the high lysine milled grain was improved.

Two procedures have been used to obtain high protein fractions by dry milling sorghum: (a) air classification and (b) tangential abrasion. Stringfellow and Peplinski (12) found that the softer sorghums yielded flours that responded better to concentration of protein by air classification. A fraction obtained from a soft sorghum variety contained over 18% protein, whereas the low protein fraction contained only 5.0% protein. Rooney et al. (13) removed successive layers of bran, aleurone, germ, and endosperm from sorghum grain using a rice pearler. Protein content of the separated fractions increased to 35% when 15% of the kernel was abraded from the grain. Further abrasion yielded less protein. Lysine rose to a maximum when 8.13% of the kernel was scraped off.

As with all cereal grain products, for optimum nutrient value and acceptability sorghum grain products require cooking and protein supplementation. Cooking may be done prior to use, but for convenience and product stability, sorghum grits may be preprocessed by either roller or extrusion cooking to yield products with a wide range of water absorption and viscosity characteristics (10). Protein

efficiency ratios (PER) of the cooked sorghum products were improved by supplementing them with either soybean or cottonseed meals. Bookwalter et al. (14) found that soy was more effective than cottonseed meal in elevating protein quality. However, lysine was still the limiting amino acid in the supplement products, as indicated by increase in PER upon addition of lysine to them. Methionine improved PER only slightly. Soy-supplemented, cooked sorghum meals containing vitamins and minerals have been used for child feeding in PL-480 sponsored programs in developing nations.

Wet milling of Sorghum

Sorghum can be wet milled by a process similar to that used for corn to produce starch and protein-rich by-products. After the grain is steeped in SO₂, the hull and germ are removed and protein and starch are separated from ground endosperm.

At present, no sorghum is commercially wet milled. The gluten meal obtained in 7.35% yield contains ca. 68% protein, but the protein is deficient in lysine (1.28%) and threonine (2.68%). A defatted germ meal fraction obtained in 8% yield contains 16.9% protein, with a lysine content of 2.44% (15). When available, sorghum gluten and germ find considerable use in feeds.

An alkaline extraction process has been developed to produce protein concentrates and starch from sorghum and to optimize the recovery of the water-soluble proteins that are highest in nutrient content (16). This process concentrates the protein by extracting the better quality protein from both germ and endosperm and yields a product that is better in protein quality than the original grain. The functional properties of the products (water-absorption and fat-emulsifying properties) are good (16). The process also produces a good quality starch in excellent yield.

TRITICALE PROTEIN PRODUCTS

Triticale is a new cereal that offers considerable promise because of its potential for greater yield compared to established crops in certain areas and because it may have greater nutritive value. It tends to be higher in protein and to have a better essential amino acid content than does wheat. The grain represents a new genus produced by man by crossing rye and wheat while maintaining the genetic complements of both parents in the progeny. Currently, interest in triticale is intense, and considerable exploratory work is progressing on its use in foods and feeds (17-20).

Preparation

Products and processing methods: Triticale grain can be ground by hand mortar, stone mills, or commercial hammer mills to give whole grain meals or flours that retain both the nutrient value and the composition of the whole grain. Whole ground triticale meals are used as components of health and novelty foods in the United States. In developing countries, these meals could be used in preparation of acceptable chappatis or tortillas. In industrialized countries, milling procedures are directed toward removing bran, germ, and aleurone layers from the most of the endosperm flour so that it has longer shelf life, lighter color, and less fiber.

Air classification of triticale flours yields high protein fractions suitable for protein supplementation. Soft, shriveled types of triticales respond best to air classification, but flours of all triticales tested gave better protein shifts than those of hard red wheat (21). Wet milling of triticale flour yields protein concentrates and starch. Sulfur dioxide steeping of triticale gives highly pure starch but low recovery of modified protein (22). Although gluten recovery by a process similar to wheat wet milling gives a good protein product, this recovery is difficult due to low

gluten strength (22). Alkaline extraction of whole triticale yields most of the grain protein, which can be recovered by isoelectric precipitation (23). Recovery of protein from triticale bran by a similar process has been reported (24).

Food Application

Bread with good loaf volume and texture cannot be prepared from triticale flour alone by standard methods because its gluten lacks the cohesive-elastic strength of the gluten in wheat doughs, and also because triticale has high protease and SH contents. Tsen (25) reports that curtailing fermentation time and adding the surfactant sodium-2-stearoyl lactylate improves loaf characteristics of triticale breads. Lorenz et al. (26) have modified absorption and mixing conditions to improve loaf volume of triticale breads. Spring variety flours work better than winter ones in breadmaking. Good loaves of bread can be prepared from 50:50 triticale-wheat flour mixtures, and the resulting loaves have a flavor like that of wheat-rye breads.

Triticale flour can be milled to produce pasta products that are slightly gray and brittle compared to durum-derived pastas (27). Quality and color can be improved by addition of eggs. Triticale flour can be extruded for production of either breakfast foods or snack items (28).

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