

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
4 May 2006 (04.05.2006)

PCT

(10) International Publication Number
WO 2006/047700 A2

(51) International Patent Classification:
A23F 3/16 (2006.01)

(21) International Application Number:

PCT/US2005/038832

(22) International Filing Date: 27 October 2005 (27.10.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

10/973,381 27 October 2004 (27.10.2004) US

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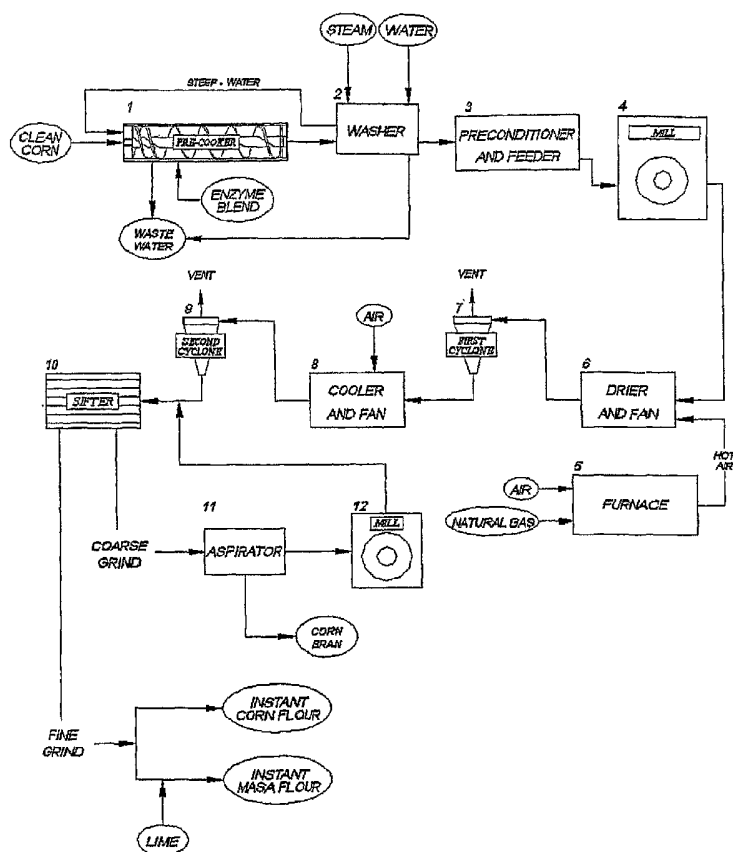
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH,

[Continued on next page]

(54) Title: CONTINUOUS PRODUCTION OF AN INSTANT CORN FLOUR FOR SNACK AND TORTILLA, USING A NEUTRAL ENZYMATIC PRECOOKING



(57) Abstract: Precooked and partially-debranned corn flour is continuously produced by an enzymatic precooking using a commercial blend of xylanase, endoamylase and endoprotease as a processing aid. The low-temperature and neutral-pH precooking with an endoenzyme solution effected a partial bran hydrolysis while avoiding excessive pregelatinization, reduced washing and corn solid loss in wastewater. Moisture content is then stabilized, followed by milling and drying at a high-temperature and short-time to produce a controlled gelatinization and denaturation in the ground kernel, cooling and further drying the dried-ground particle. A fine particle size or flour is separated and recovered from the coarser particle which is also segregated to isolate a partially hydrolysed bran fraction for integral flour or animal feed diet, remilling and sieving the coarser particle to produce an instant corn flour for snack, and admixing the fine particle with lime to obtain a masa flour for tortilla and other corn foods.



GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

CONTINUOUS PRODUCTION OF AN INSTANT CORN FLOUR FOR SNACK AND TORTILLA, USING A NEUTRAL ENZYMATIC PRECOOKING

This application is a Continuation-In-Part of Application Serial No. 10/653,361 filed August 28, 2003, which is in turn a Continuation-In-Part of Application Serial No. 10/231,291 filed August 30, 2002, issued as U.S. Patent no. 6,638,554. The entire contents of each of the above-identified applications are hereby incorporated by reference.

BACKGROUND OF INVENTION

1. Field of the invention

The present invention relates to a method of low-temperature and neutral-pH precooking for the production of corn flour and, more particularly, to one that achieves continuous partial hydrolysis of the insoluble heteroxylans, starchy and proteinaceous bran cell-walls while avoiding excessive pregelatinization with a xylanase, endoamylase and endoprotease blend as a processing aid during the manufacture of an instant corn flour for the elaboration of snack and tortilla foods.

2. Description of Related Art

The production of high-quality masa flour can be produced by conventional techniques only if the food-grade dent corn has the following characteristics: uniformity in kernel size and hardness, low number of stress-cracks and kernel damage and ease of pericarp removal during the lime-water cooking process. The mature kernel has four

separable components, on a dry weight basis: tip cap (0.8-1.1%), pericarp or bran (5.1-5.7%), endosperm (81.1-83.5%), and germ (10.2-11.9%). In dry or wet-milling processes the bran includes the pericarp, tip cap, aleurone layer (isolated with bran) and adhering pieces of aleurone/starchy endosperm as well. A native corn bran contained starch (4-22%) and protein (5-8%) arising from the endosperm tissue and glycoprotein pericarp as well (Saulnier et al. 1995 and Hromadkova et al. 1995). Nixtamalized corn flour (NCF) is produced by the steps of alkaline cooking of corn, washing, milling the nixtamal and drying to give corn masa flour. This flour is sieved and blended for different product applications and it is usually supplemented with additives before packaging for commercial table or packaged-tortilla and snack production. Although the pericarp or bran is partially removed during the alkaline-cooking and washing process stages, there is still fiber left from the corn kernel (Montemayor and Rubio, 1983, U.S. Pat. No. 4,513,018). Whole Nixtamalized corn flour or masa flour can contain from 7-9% of total dietary fiber or bran with 6-8% mainly consisting of insoluble fiber on a dry basis (Sustain, 1997, U.S. Pat. No. 6,764,699).

The cell walls or non-starch polysaccharides (NSP) are the major corn dietary fiber components and are composed of hemicellulose (heteroxylan or pentosan and β -glucan: 4.4-6.2%), cellulose (2.5-3.3%) and some lignin (0.2%). According to Watson (1987: Tables IV and VII), the corn pericarp/tip cap makes up about 5-6% and aleurone-endosperm has about 2% of the kernel dry weight. This pericarp also contains 90% insoluble fiber (67% hemicellulose and 23% cellulose) and only 0.6% soluble-fiber (soluble-arabinoxylan and β -glucan). It is estimated that dietary fiber in both pericarp or bran (4.9%) and endosperm (2.6%) make up 80% of the total dietary fiber. The corn insoluble fiber is mainly found in the pericarp and endosperm (aleurone and starchy)

which make up 68% of the total dietary fiber (9.5% in a dry-weight basis). The corn bran layers comprise the outer (beeswing or hull), inner (cross and tube cells), nucellar layer and endosperm (aleurone and starchy) cell-walls. The innermost tube-cell layer is a row of longitudinal tubes pressed tightly against the aleurone layer. Next there is a very loose and open area called the cross-cell layer, which has a great deal of intercellular space. These areas provide capillary interconnections between all cells, which facilitate water absorption. The pericarp extends to the base of the kernel, uniting with the tip cap. Inside the tip cap there are spongy-branched cells openly connected with the cross-cells.

Unlike corn endosperm, in which soluble fiber amounts to 12% of the total fiber (4.1%), in whole wheat, soluble fiber represents 22% of total fiber (about 20% of the flour water-uptake is bound to the soluble pentosan fraction). Arabinoxylan is a complex polymer (20,000-170,000 Daltons) with a linear backbone of (1,4)- β -xylopiranosyl units to which substituents are attached through O2 and O3 atoms of the xylosil residues (mainly, α -L-arabinofuranosyl). This polymer is apparently linked to the cellulose skeleton in the corn cell wall by ester linkage cross-bonding through ferulic and diferulic acid (Watson, 1987). However, heteroxylan insolubility in corn bran might be due to protein-polysaccharide linkages (pericarp glycoprotein or extensin) and a highly branched structure (23% of the xylan backbone does not bear side-chains) as opposed to wheat bran (Saulnier et al., 1995).

During alkali-cooking and/or steeping, there are chemical and physical changes such as nutrient losses along with partial pericarp or bran removal, degradation of the endosperm periphery with starch gelatinization/swelling and protein denaturation in the precooked corn kernel. The most important nutritional modifications are: an increase in the calcium level with improvement in the Ca to P ratio, a decrease in insoluble dietary fiber

and zein-protein, a reduction in thiamin and riboflavin, an improvement of the leucine to isoleucine ratio reducing the requirement for niacin, and leaching the aflatoxins into the wastewater (Sustain, 1997).

The known cooking methods (batch or continuous) have been proposed as the critical variables (Sahai et al., 2001) which determine soluble-solid loss (1% to 1.6% COD) in limewater residue for anaerobic biodegradation (Alvarez and Ramirez, 1995). Dry solid matter (1.5%-2.5%) includes an average of 50-60% dietary fiber, 15-20% ash, 15% starch, 5-10% protein and 5% fat. Bryant et al., (1997) showed an optimum change in starch behavior at a lime level similar to the corn masa industry where starch gelatinization indicators (enzyme digestion, water retention capacity, starch solubility and DSC-peak temperature = 69° to 75°C) are increased with lime addition of 0% to 0.4%, peaking at 0.2%. They also found a peak-viscosity temperature reduction upon the addition of lime up to 0.5%, indicating faster granule swelling that requires less thermal energy. Corn pericarp nixtamalization (Martinez et al., 2001) has a first-order stage associated with a fast dissolution of hot-water soluble fractions as starch and pectin, and alkali-soluble fat. A second stage is due to a slow alkaline-hydrolysis of the hemicellulose-cellulose-lignin structure with a higher hemicellulose loss proportional to alkaline-pH concentrations.

Arabinoxylan degrading enzymes include xylanases (1,4- β -D-xylan *xylanohydrolase*, EC 3.2.1.8) and β -xylosidases (1,4- β -D-xylan *xylohydrolase*, EC 3.2.1.37). The former endoenzyme randomly hydrolyze the insoluble and soluble xylan backbone (EC 3.2.1.8) whereas the latter exoenzyme hydrolyze xylose from the non-reducing end of the xylose-polymer (EC 3.2.1.37). Xylose is not usually the major product and it is typically produced after xylobiose and xylotriose (smallest oligomer). Virtually all xylanases are endo-acting as determined by chromatography or their kinetic properties

(substrate and product formation), molecular weight and pH (basic or acidic) or its DNA sequence (crystal structure). They can be structurally classified into two major families or isoenzymes (F or 10 and G or 11) of glycosyl hydrolases (Jeffries, 1996). F10 xylanases are larger, with some cellulase activity and produce low DP oligosaccharides (less specific); F11 are more specific for xylan and with lower molecular weight (i.e., *B. Circulans* and *T. harzianum*).

In addition, the Enzyme Technical Association (ETA, 1999; FDA, 1998) classified as carbohydrases the following hemicellulases (trivial name): a) endoenzymes (EC 3.2.1.32= β -1,3-xylanohydrolase, 78=mannanohydrolase and 99=arabinohydrolase) and b) exoenzymes only attack branches on the xylose-polymer (pentosan), producing xylo-oligomers (EC 3.2.1.55= α -L-arabinofuranosidase) or producing acids (*glucuronic-acid glycosilase* and *ferulic-acid esterase*). Currently recognized endoenzymes (xylanases) and exoenzymes produced from *A. niger* (EC 3.2.1.8 and 37,55), *A. oryzae* (EC 3.2.1.8 or 32), *B.subtilis* (EC 3.2.1.99), and *Trichoderma longibrachiatum* (formerly *reesei*; EC 3.2.1.8) are Generally Recognized As Safe (GRAS; 21 CFR 182, 184 and 186) and require no further approval from the U.S. Food and Drug Administration or Recognized As Safe (RAS in Europe: Mathewson, 1998). However, direct and indirect food additives (i.e., packaging materials) are regulated in 21 CFR 172 and 174-178 as well. Secondary direct additives, a sub-class of direct additives, are primarily Processing Aids which are used to accomplish a technical effect during food processing but are not intended to serve a technical or as a functional additive in the finished food. They are also regulated in 21 CFR 173 (Partial List of Enzyme Preparations that are used in foods). Finally, all GRAS Substances produced through recombinant-DNA which were widely consumed prior to 1958, and which have been modified and commercially introduced after

1958 must comply with regulatory requirements proposed in 21 CFR 170.3 (GRAS Notice).

The benefits of using a commercial xylanase (endoenzyme) in cereal flours instead of a non-specific hemicellulase (exo- and endoenzyme) preparation are a reduction in side activities (cellulase, beta-glucanase, protease and amylase) and a reduction of dough-stickiness. Arabinoxylan degrading enzymes with well defined endo-acting and exo-acting activities have become commercially available, for food and feed, from the following companies: Amano, Danisco-Cultor, EDC/EB, Genencor, Gist-Brocades-DSM, Iogen, Novozymes, Primalco, Quest, Rhodia and Rohm. Suggested applications for commercial xylanases (endopentosanases) and hemicellulases (pentosanases) mentioned in the literature include: 1) improving the watering of spent grains and energy reduction during grain drying; 2) facilitation of dough formulation with less water, reduction of stickiness in noodle and pasta production; 3) reduction in the water content when formulating grains for flaking, puffing or extrusion; 4) retarding staling or hardening in bread; 5) relaxing dough for cookie and cracker production and use of sticky cereal flours in new product formulations; 6) increase in bran removal when added to tempering water; and 7) reducing both steeping time and starchy fiber in corn wet milling.

A complex set of conditions determines bakery product shelf life, so the food formulator has three basic approaches to crumb softness: prevent moisture transfer; prevent starch recrystallization; and hydrolyze starch. Crumb staling is marked by many physicochemical changes which occur in the following order: hardening and toughening of the crumb (starch retrogradation); appearance of crumbliness; and moisture loss by evaporation. Commercial amylases act as anti-staling agents by breaking down gelatinized starch during baking. Some commercial microbial amylases (ETA, 1999;FDA, 1998) are

listed by name and source are: a) endo-amylase (*A. oryzae/niger*, and *R. oryzae/niveus*: EC 3.2.1.1); b) exo-glucoamylase/exo-amyloglucosidase (*R. oryzae/niveus* and *Aspergillus oryzae/niger*: EC 3.2.1.3); and c) endo-pullulanase and endo-amylase (*B. subtilis*, *B. megaterium*, *B. stearothermophilus* and *Bacillus spp.*: EC 3.2.1.33,41/60 and EC 3.2.1.133). Genetic engineering technology has been used to develop amylases with endo or exo-acting (maltogenic) activity with intermediate thermostability (<65°C) and *B. stearothermophilus* falls into this category. These novel amylases are fully inactivated during baking while yielding a soft crumb without gumminess even at higher dosages. Lopez-Mungia et al. (MX Patent 952,200) described an enzymatic process (with endoamylases) to obtain corn tortillas (from nixtamal or nixtamalized corn flour), which delays staling during frozen storage. Furthermore, the commercial enzyme products normally contain one or more enzymatic activities such as: carbohydrase (amylase, xylanase), protease and esterase. These hydrolases are enzymes catalyzing the hydrolysis of various bonds: EC 3.2 *Glycosylase* is a carbohydrase acting on O-glycosyl bonds (EC 3.2.1) and EC 3.4 *Peptidase* is a protease acting on peptide bonds. The proteases are further divided into "exopeptidases" acting only near a terminus of a polypeptide chain (aminoacid polymer/protein) and "endopeptidases" acting internally in polypeptide chains. The usage of "peptidase" is synonymous with "protease" as it was originally used. Two sets of sub-classes are recognized, those of the endoproteases (EC 3.4.21-24/99) and those of the exoproteases (EC 3.4.11-19). The endoproteases are mainly divided on the basis of catalytic mechanism and specificity: Serine proteases (EC 3.4. 21 acting at alkaline-pH), Cysteine/Metallo proteases (EC 3.4.22/24 acting at neutral-pH) and Aspartic proteases (EC 3.4.23 acting at acid-pH). Microbial proteases fall into three broad groups: a) acid proteases with maximal activity between pH 2 and 4, b) neutral proteases at pH 7-8,

inhibited by metal-chelating agents and c) alkaline proteases at pH 9-11, cleaving a wide range of peptide and ester bonds as well. *Bacillus* endoproteases can be divided in two types: A-group (*B. subtilis*, *B. licheniformis* /*B. pumilus*: <50°C) does not produce neutral protease or amylase, and B-group (*B. subtilis* NRRLB3411, *B. amyloliquefaciens* and *B. subtilis* var. *amylosacchariticus*) produces a neutral (*B. megaterium*/*stearothermophilus*: ~70°C) and endo/exoamylase as well (Keay et al., 1970a,b).

A moderate hemicellulase addition decreases water uptake in wheat dough, whereas using a xylanase increases water binding and soluble-xylans as well for a high-moisture bread product. On the contrary, if starch gelatinization is to be minimized, a higher endoenzyme or xylanase addition is desirable and hydrolysis of the soluble fraction releases water for low-moisture cookie or cracker products (EPA Patent 0/338787). Therefore, a suitable level of xylanase results in desirable dough softening without causing stickiness, thereby improving machinability during forming and baking operations. Haarasilta et al. (U.S. Pat. No. 4,990,343) and Tanaka et al. (U.S. Pat. No. 5,698,245) have proposed that a preparation of hemicellulase or pentosanase with a cellulase (Cultor/Amano) causes decomposition of wheat insoluble fiber for bread volume increase. Rubio et al. (U.S. Pat. No. 6,764,699) have improved the flexibility and elasticity of packaged corn tortillas after 7 days of ambient storage by adding a fungal mix of xylanase and cellulase (>100 ppm) to a whole nixtamalized corn flour.

Antrim et al. (CA Patent 2,015,149) disclosed a process of preparing a shredded, farinaceous product by cooking whole grain (wheat), treating it with a microbial isoamylase, tempering (i.e., holding) and forming in order to bake or toast the shredded wheat product. Tobey et al. (U.S. Pat. No. 5,662,901) have used an enzyme formula (>200 ppm) and conditioned the wet or soaked grain (sorghum) for at least 30 minutes. The

microbial enzymes comprised a hemicellulase, an amylase, a pectinase, a cellulase and a protease to increase both animal weight gain and feed use efficiency. Van Der Wouw et al. (U.S. Pat. No. 6,066,356) also reported the use of a recombinant-DNA endo-arabinoxylanase (Gist Brocades) breaks down the water-insoluble-solids (~1.5%) from degermed maize and increases their in-vitro digestion (13%-19%) for animal feed or in wheat flour for improving its bread volume (~9%).

A pilot process (WO Patent 00/45647) for the preparation of a modified masa foodstuff used a reducing agent (metabisulfite) or an enzyme as a processing aid (disulfide isomerase or thiol-protease/Danisco) with masa or corn prior to nixtamalization such that the native protein is modified. Jackson et al. (U.S. Pat. No. 6,428,828) disclosed a similar process where whole-kernel corn was steeped and digested with a food-grade commercial alkaline-protease (< 1000 ppm: 50°C-60°C; pH>9) which altered zein structure similarly to alkali-cooking with a partial gelatinization (~20%-40%).

A novel transgenic thermostable-reductase enzyme was cloned in corn (high-protein) mainly to enhance extractability and recovery of starch and protein important in flaking grit production and in masa production. Reduction of protein disulphide bonds alters the nature of corn flour (as a wheat substitute from high-protein corn) when steeping the corn grain between 45°C and 95°C instead of using sulfite salts. The critical steeping is required to soften the kernel and then to loosen starch granules from the complicated matrix of proteins and cell wall material that makes up the corn endosperm (WO. Patent 01/98509).

Tortilla is the main edible corn product in North and Central America. It is a flat, round, unleavened and baked thin pancake (flat-cornbread) made from fresh masa (ground nixtamal) or corn dough prepared from nixtamalized corn flour (masa flour). It

might be mentioned that tortilla, when manually or mechanically elaborated and without additives of any kind, has a maximum shelf life of 12 to 15 hours at room temperature. Afterwards they are fermented or spoiled by microorganisms and becoming hard/stale (starch-protein aggregation) due to a physicochemical change in the starch constituent of either stored or reheated tortilla. It is known that tortillas when kept under conditions in which no moisture is lost (plastic package), nevertheless become inflexible with time and break or crumble easily when bent. In northern South America, particularly in Colombia and Venezuela, hard endosperm corn is processed with dry milling technology without wastewater and it is further converted into a precooked, degermed and debranned flour for traditional foods. Its consumption is mainly in the form of “arepa”, which is a flat or ovoid-shaped, unleavened, and baked thick-pancake made from instant flour. In other South American countries, corn meal (polenta) and corn flour as well are used for empanada, pancake and snack food (FAO, 1993).

Food fermentation processes are reliant on both endogenous and microbial enzymatic activities for the degradation of fibers, starches, proteins, anti-nutritional and toxic factors. In some cases, microbial processes are associated with indigenous fermentation processes, which exhibit unique properties. Microorganisms are currently the primary source of industrial enzymes: 50% are derived from fungi and yeast; 35% from bacteria, while the remaining 15% are either of plant or animal origin. Microbial enzymes are commercially produced either through submerged fermentation or solid-substrate fermentation technologies. The use of biocatalysts or enzymes has the potential to increase productivity, efficiency and quality output in agro-industrial processing operations in many emerging countries. These biochemical processes generally have requirements for a simple manufacturing base, low capital investment and lower energy consumption than

other food processing unit operations. Alkaline and neutral-pH fermentations of various beans (soy and locust), seeds, and leaves provide protein/lipid rich, flavorsome, low-cost food condiments to millions of people mainly in Africa and Asia (Nigerian dawadawa/ogiri, Sierra Leone ogiri-saro, Japanese natto, Indian kenima, Indonesian cabuk/semayi). Based upon the use of *Bacillus* spp. (*B. subtilis*, *B. licheniformis*, *B. pumilus*), the fermentations are primarily proteolytic, yielding amino acid/peptide-rich mixtures without microbial amylase and lipase activities mainly in seeds (Steinkraus, 1996). Pozol is a fermented corn doughball (from nixtamal or lime-treated maize) produced and consumed, as a beverage/porridge, by the indigenous and mestizo population in S.E. Mexico. It is a probiotic fermentation involving at least five interacting groups which include the natural flora from a freshly prepared dough or nixtamalized corn flour (heat-resistant *Bacillus* spp. and *Actinomycetes* spp.). *Agrobacterium azotophilum* (reclassified as *Bacillus subtilis*: NRRL B21974) and *K. pneumonia* (*E. aerogenes*), both of which grow in nitrogen-free media and increase the aminoacid nitrogen and likely the total-nitrogen during this solid-substrate fermentation. The other groups include a lactic-acid bacterium (amylolytic *Lactobacillus* sp.), which increases its flavor (0.7% lactic-acid) while lowering the alkaline pH (from 8 to ~5 at 24-48 hours); *C. tropicalis* which contributes to an alcoholic/fruity aroma, and *G. candidum* which produces aroma and spongy texture (Ramirez and Steinkraus, 1986; Steinkraus, 2004). On the other hand, a corn wet-milling process for starch production involves an acid (pH < 5) fermentation during steeping or soaking whole corn kernels counter-currently (24-48 hours at 45-50°C). The purpose is to soften the endosperm and to break the disulfide-bonds holding the protein matrix together. Steeping is a diffusion limited unit operation where two steep-water chemical and biochemical aids are required (with ~0.10-0.25% sulfur dioxide and

~0.5-2.0% lactic-acid usually produced by *Lactobacillus spp.*). They can diffuse into the corn kernel through the base end of the tip cap, move through the cross and tube cells of the pericarp to the kernel crown and into the endosperm (Watson, 1987). The main result of a lactic fermentation is a dispersion of endosperm protein/zein and an enhancement of starch release during subsequent milling for acid-fermented corn gruels/porridges such as: Ghanaian kenkey, Nigerian ogi (industrial), Kenyan uji and South African mahewu (Steinkraus, 1996 and 2004).

Properly processed industrial corn or masa flour simplifies the production of tortilla and snack products, because the customer eliminates management techniques required for wastewater treatment, securing, handling and processing corn into fresh masa for tortillas and snacks. However, an instant corn flour might have the following quality and cost disadvantages: high cost, lack of flavor and poor texture in masa and third-generation (3G) corn foods. These may include extrusion cooking, followed by cooling, holding (aging) and drying to make “snack pellets” which are expanded by frying to make the final snack product. Another example is breakfast cereals made by cooking whole grain (wheat, rice, or corn), followed by cooling, tempering (conditioning), shredding, forming into “biscuits” and baking.

Corn processors can generate added value from their industrial operations in one of three approaches: developing new products from new hybrids, increasing the yield of traditional products from corn, and improving process efficiency at a lower unit cost. In the past, this has been done by methods and using an apparatus in which the grain is cooked and/or steeped in a lime-water solution such as those disclosed in U.S. Pat. Nos. 2,584,893, 2,704,257, 3,194,664, and 4,513,018. These prior art methods for the industrial production of corn dough or masa flour involve accelerated cooking and steeping times

with large amounts of solids losses (~1.5-2.5%) in the liquid waste. In addition, essential nutrients such as vitamins and some amino acids are lost, depending on the severity of the cooking, washing and drying operations.

Many and varied methods for the production of instant corn flour for food products involving reduced amounts of water with low-temperature cooking and short-time processing for a high yield of the end product have been developed, as reflected by the following U.S. Pat. Nos. 4,594,260, 5,176,931, 5,532,013, and 6,387,437. In this connection, reference is made to the following U.S. Pat. Nos. 4,594,260, 5,176,931, 5,532,013, and 6,265,013 also requiring a low-temperature drying. On the contrary, U.S. Pat. Nos. 4,513,018, 5,447,742, 5,558,898, 6,068,873, 6,322,836, 6,344,228 and 6,516,710 used a high-temperature dehydration or cooking in place of a low-temperature cooking.

Having in mind the disadvantages of the prior art methods, several studies not only have used a low-temperature precooking with minimum wastewater, but also separate corn fractions as reflected by the following U.S. Pat. Nos. 4,594,260, 5,532,013, 6,025,011, 6,068,873, 6,265,013, 6,326,045 and 6,516,710.

A few applications for enzymatic steeping were also tested to convert a traditional masa processing with reduced wastewater into a novel biochemical process (WO Patent 00/45647 and U.S. Pat. No. 6,428,828). Although the above described prior art methods are capable of either an acid or an alkaline-enzymatic precooking or steeping of the whole corn for either modified masa or masa flour processing, a continuous industrial application using instead a blend of xylanase, an endoamylase and an endoprotease as a processing aid, at a neutral-pH, was still unavailable in the market at the time of the invention.

SUMMARY AND OBJECTS OF THE INVENTION

Accordingly, it is an object of this invention to provide a complete departure from the prior art accelerated precooking methods of thermal, mechanical, chemical and enzymatic or bioprocessing of whole corn in order to control not only a starchy endosperm gelatinization but also protein denaturation without using chemicals during production of an instant corn flour for snack and tortilla foods.

It is another object of this invention to use low-temperature cooking with a microbial xylanase, endoamylase and endoprotease solution for a partial hydrolysis of bran heteroxylans, starchy and proteinaceous cell-walls during the continuous production of precooked corn flour. A combined use of a commercial xylanase, endoamylase and endoprotease is preferred.

Another object is to use an industrial method and apparatus involving a low-temperature, neutral-pH precooking which not only solubilize corn cell-walls along with a slower water diffusion effecting a controlled starch granule swelling, but also results in a reduced corn solid loss.

The above and other objects and advantages of the invention are achieved by a new continuous process applied to the production of precooked corn flour or instant corn flour for snack and tortilla, embodiments of which include a short-time corn precooking followed by a low-temperature and neutral-pH precooking with a xylanase, endoamylase and endoprotease as a processing aid so as to effect a partial hydrolysis of insoluble bran layers with decreased gelatinization and denaturation, reduced washing and

corn solid loss of precooked kernel, stabilization of the moisture content to a desired optimum level for milling and drying the preconditioned kernel to produce a uniform partial gelatinization, cooling and drying the dry-ground particle, separating and recovering the fine grind so produced from the coarser grind while the latter is further aspirated to remove a partially hydrolysed bran fraction for integral flour or animal feed diet, remilling the isolated coarser grind and further sieving it to obtain an instant corn flour for snack, and admixing only a fine flour with lime to produce masa flour for tortilla and derivatives thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the description, which follows, and from the appended drawing in which the sole drawing figure depicts an embodiment of this invention in a block-type flowchart illustrating the continuous and industrial bioprocess using a low-temperature and neutral-pH precooking with a xylanase, endoamylase and endoprotease solution as a processing aid.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1, there is depicted, in flowchart form, an embodiment of the present invention. It includes a pre-cooker 1; a washer 2; a preconditioner 3 with a feeder; a primary mill 4; a furnace 5; a dryer 6 with a fan; a first cyclone separator 7; a cooler 8 with an associated fan; a second cyclone separator 9; a sifter 10; an aspirator system 11; and a secondary mill 12.

The pre-cooker 1, whose design is known per se, is fed with cleaned corn and a steam-heated steepwater (70°C to 85°C) recycled from the washer 2 to form an aqueous suspension (corn to water ratio of about 1:1 to 1:2.0). The corn kernel is parboiled in order to loosen their bran cell walls and partially hydrated from a range of 9%-12% to a range of about 24%-32% for a period of about 20 to about 40 minutes. Next, a microbial xylanase, endoamylase and endoprotease solution is continuously added as a food processing aid into the pre-cooker at a low-temperature range of about 50°C to 70°C for another period of 10 to 75 minutes. This allows the enzymatically precooked kernel to be produced at moisture contents of between 32% and 37%, while the pH is maintained at a neutral-pH of about 6.0 to about 8.0 with the addition of a 10% solution of xylanase, endoamylase and endoprotease. The solution is provided in an amount representing 0.025% to 0.25% of the corn kernel (by weight). Preferably, the solution is provided in an amount representing 0.025% to 0.180% of the corn kernel (by weight). By controlling the steam heating along with the kernel residence time, it is possible to partially precook the corn at a temperature of about 50°C to 85°C for a total period of 30 to about 115 minutes in order to soften their bran layers. The neutral-pH precooking may be performed so that it is only the mixture of corn kernel, the steepwater, and the microbial solution that are subjected to precooking. It is possible that the microbial solution may include only a carrier and one or more of xylanase, endoamylase and endoprotease.

Wastewater loss in the precooker is replaced with recycled steam-heated steepwater from the washer 2, which is regulated to maintain the solid content of the solution from about 1.0% to about 1.5%. The industrial pre-cooker performs a partial hydrolysis of corn bran and starchy/proteinaceous cell-walls that promotes a fast water diffusion through the pericarp and tip cap layers, and later on a slow penetration via the

endosperm and germ cell-walls increasing starch granule swelling. This low-temperature precooking (<70°C) further controls both insoluble fiber and starch/protein solubilization as well (from about 0.5% to about 1.5% water-extractable solids, based on corn kernel), thus permitting at least a 35% reduction in soluble solids concentration as compared to the traditional batch and continuous alkali cooking (1.5-3.0%: U.S. Pat. Nos. 6,516,710 and 4,513,018). The partially precooked corn suspension is then passed to a washer 2 where it is sprayed with hot water at a temperature of about 75° to 90°C during 30 to 60 seconds, which also serves to increase water absorption and wash off corn solids with denatured endoenzymes as wastewater.

The washed corn is thereafter passed to a preconditioner 3, where the neutral precooked kernel is equilibrated at 55°C to about 75°C to obtain a residual moisture content of about 34% to about 39% for about 15 to about 60 minutes.

Thereafter, the preconditioned corn is fed through a feeder, whose design is known per se, to a primary mill 4 such that the premilled corn and hot air coming from a furnace 5, is mixed and partially cooked by an industrial dryer 6 whose design is known per se. The premilled kernel is thereby flash dried at a high-temperature from 190°C to about 230°C for a short time of 5 sec to about 30 sec. Its starchy endosperm is partially gelatinized or precooked to yield a moisture content of 16% to about 20% at 60°C to 75°C depending on the granulation being produced.

Moisture laden-hot air (110°C to 120°C, and 11% to 13% moisture) is extracted with a first cyclone separator 7 so that further moisture extraction may take place by impelling the drier material through a cooler 8 with an associated fan, thus further decreasing the moisture content from 16-20% to about 9-12% (similar to incoming corn).

After further extraction of moisture laden-warm air (95°C to 100°C) with a second cyclone separator 9, the precooked dry particle is directed to a sifter 10 where the fine fraction is separated (under 20 to 100 mesh) as instant corn flour and the coarser fraction is further separated.

The latter coarse fraction is further separated in the aspirator system 11 wherein two fractions are obtained, a light-bran fraction which is isolated as feed or for integral flour with a moisture content between 9% to 12% (representing from about 3% to about 6% of the total weight of incoming cleaned corn), and a heavy coarser fraction that is remilled in a secondary mill 12. The milled product from secondary mill 12 is recycled to the sifter 10 for further sieving and producing a homogeneous corn flour for snack. If desired, the instant corn flour can be admixed with lime (from 0.05% to about 0.25% based on precooked flour) to produce a masa flour for making tortilla or corn-based foods.

For use in snack manufacture, the instant corn flour is preferably rehydrated by mixing with warm water from a 1:0.8 to about 1:1.0 weight ratio to form a corn dough (45% to 50% final moisture) for snack elaboration (from about 15% to about 30% total oil).

For use in tortilla manufacture, the masa flour made from the present method can be rehydrated with water from a 1:1.1 to about 1:1.3 weight ratio for a masa dough (50% to 60% final moisture) used in tortilla and corn-based foods (from 45% to 50% moisture).

In this method, the novel neutral enzymatic precooking results in a 35% to 40% reduction in wastewater corn solids, with correspondingly lower sewage and energy costs, as compared to the industrial methods (1.5%-3.0%). Furthermore, the enzymatic precooking of the invention allows a 50% reduction in lime use if an instant masa flour

were produced to improve new flavors in corn-based foods as third-generation snacks. The low-temperature precooking (50°C-70°C) at neutral-pH (6-8) using a xylanase, endoamylase and endoprotease solution (0.025%-0.25%) not only aids in depolymerization of the insoluble cell-wall biopolymers but also improves its bran removal and recovering its aleurone layer as flour. The endoenzymes partially hydrolyse the pericarp, aleurone and starchy cell-walls effecting a simultaneous water diffusion with a reduced gelatinization and denaturation without using a low-lime (U.S. Pat. Nos. 6,516,710, 6,428,828, 6,387,437 and 6,344,228) or a low-sulfite addition (U.S. Pat. No. 6,322,836).

There is furthermore a potential in corn flour yield from 94% to 97% of the total weight of enzymatically pre-cooked corn as compared to the commercial alkali-cooking process, which yields 88%. Whereas the instant corn flour produced by the novel method may thus comprise a higher than 95% average yield of flour per kilogram of corn, the debranned and degermed flour produced by a typical arepa process obtains only a 65% to 70% yield, or a 80% to 85% yield for an integral arepa flour (U. S. Pat. No. 6,326,045).

Still further, the low-temperature and enzymatically precooked corn flour produced by the present method has a higher nutritional value as compared to the conventional methods, with more dietary fiber and fat contents than the commercial corn flours (INCAP, 1961, Cuevas et al., 1985 and FAO, 1993). Epidemiological studies have shown that regular consumption of fruits, vegetables and whole grains is associated with reduced risk of chronic diseases such as cancer, coronary heart disease and diabetes. Obesity leads to heart disease and cancer. Approximately 35% of deaths due to cancer in the United States are related to diet. The USDA has recommended eating 3-5 servings/day (> 5.1g-fiber) of whole grains (wheat, rice and corn) which comprise the base of the food guide pyramid. An AACC- food health claim is based on a 51% whole grain by weight of

a finished product (as integral flour or a nixtamalized corn flour with 7-9% total fiber: US. Pat. No. 6,764,699).

From the foregoing, it will be apparent that it is possible to manufacture a precooked and partially-debranned corn flour for snack and masa flour with a novel enzymatic process which is efficient because of partial hydrolysis of cell-walls or solubilization of the endosperm periphery with starch pregelatinization and protein denaturation in the precooked corn kernel, wherein some of the nutrient losses that would have been present but for the features of this invention is prevented.

It is to be understood that the embodiments of this invention herein illustrated and described in detail, are by way of illustration and not of limitation. Other changes and modifications are possible and will present themselves to those skilled in the prior art and by the spirit of the appended claims.

We claim:

1. A biocatalytic process for the continuous production of precooked and partially debranned corn flour for snack and tortilla foods, comprising the steps of:

precooking cleaned corn kernel with hot water to form a suspension of corn and water, having a corn to water ratio between 1:1 and 1:2.0,

further precooking the corn kernel at a neutral-pH with a solution comprising at least one endoenzyme selected from the group consisting of a xylanase, endoamylase and endoprotease, to effect a partial hydrolysis of insoluble heteroxylans, and starchy and proteinaceous bran cell-walls,

washing said precooked kernel to remove soluble solids and denatured said at least one endoenzyme, stabilizing a moisture content of said washed precooked kernel,

milling said washed precooked corn kernel and drying said milled corn kernel for further pregelatinization,

cooling and further drying said milled and dried corn kernel with ambient air,

sifting said milled corn to obtain a fine fraction, under 20 to 100 mesh to produce a corn flour with fine particle size, and a coarse fraction, and

aspirating said sifted coarse fraction to remove an hydrolyzed corn bran for integral flour or feed diet

2. The method of claim 1 wherein said solution in said further precooking step comprises a mixture of a xylanase, endoamylase and endoprotease.

3. The method according to claim 1 wherein said hydrolysed corn bran is a light fraction, representing a minimum yield from 2% to about 4% of the total weight of corn kernel.

4. The method of claim 1, wherein wastewater produced by the neutral enzymatic precooking and washing steps comprises a corn solids reduction in a range of 35% to about 40%.

5. The method in accordance with claim 1, further comprising rehydrating said corn flour by mixing with warm water from a 1:0.8 to about 1:1.0 weight ratio to form a corn dough.

6. The method in accordance with claim 1, further comprising a step of treating said corn flour with 0.05% to 0.25% by weight lime to produce a masa flour.

7. The method according to claim 6, further comprising a step of rehydrating said masa flour with water from a 1:1 to about 1:1.3 weight ratio to form a masa dough.

8. The method of claim 5, wherein the corn dough has a final moisture content between 45% and 50% used in snack elaboration.

9. The method of claim 7, wherein the masa dough has a moisture in a range of 50% to 55% used in tortilla and corn-based foods.

10. The method of claim 1, wherein the hot water used in the precooking step is recycled from a downstream washer.

11. The method of claim 1, wherein the at least one endoenzyme is selected from microbially derived enzymes that are recognized as at least one of GRAS substances and used as processing aids.

12. The method of claim 1, wherein the further precooking step is performed up to a denaturing temperature of one of said xylanase, endoamylase and endoprotease.

13. The method of claim 1, wherein in the milling and drying step, the drying is performed with a high temperature-short time drier.

14. The method of claim 1, further comprises remilling the aspirated coarse fraction.

15. The method of claim 14, wherein the remilled coarse fraction is recycled to the sifting step.

16. The method of claim 2, wherein the solution is provided in an amount representing 0.025% to about 0.25% of the corn kernel by weight.

17. The method of claim 1, wherein the further precooking step is performed at a temperature lower than the temperature of the preceding precooking step.

18. The method of claim 17, wherein the further precooking step is performed at a temperature in the range of about 50°C to 70°C.

19. The method of claim 2, wherein the neutral pH of the further precooking step is within a range of about 6.0 to about 8.0.

20. The method of claim 1, wherein the solution in the further precooking step comprises endoprotease and xylanase.

21. The method of claim 1, wherein the solution in the further precooking step comprises endoprotease and endoamylase.

22. The method of claim 1, wherein the further precooking step heats only a mixture consisting essentially of the corn kernel, the steepwater, and the solution.

23. The method of claim 22, wherein the solution consists essentially of the at least one endoenzyme and an endozone carrier.

24. The method of claim 2, wherein the further precooking step heats only a mixture consisting essentially of the corn kernel, the steepwater, and the solution.

25. The method of claim 24, wherein the solution consists essentially of the endoenzymes and an endozone carrier.

26. The method of claim 19, wherein the neutral pH of the further precooking step is within a range of 7.0 to 8.0.

27. The method of claim 16, wherein the solution is provided in an amount representing 0.025% to about 0.180% of the corn kernel by weight.

