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[54] **MILLING OF CEREAL GRAINS AND PROCESSING OF PRODUCTS DERIVED THEREFROM**
8 Claims, 1 Drawing Fig.

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[50] **Field of Search** ..... 99/80, 80 B

[56] **References Cited**

UNITED STATES PATENTS

3,261,690 7/1966 Wayne 99/80
3,421,902 1/1969 Wayne 99/80

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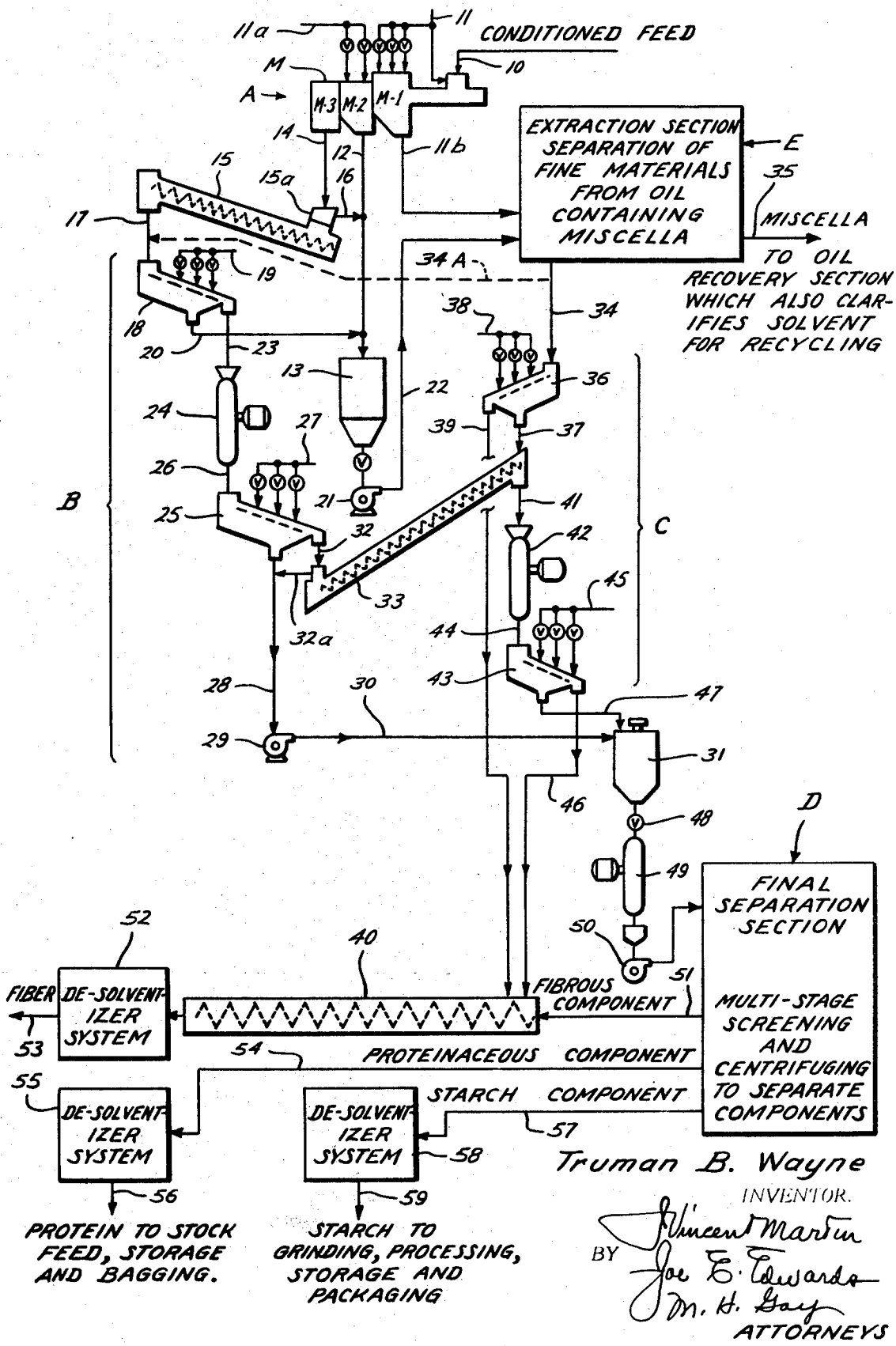
ABSTRACT: This invention relates to improvements in milling and processing cereal grains and has, as its primary objective, the separation and recovery of the fibrous, proteinaceous and starchy components of said cereal grains in more concentrated, purer states. The improved results are obtained by separating and removing the major portion of the fibrous components from the system as early as possible in the overall process so that the separating section, in which the final separation between said fibrous, proteinaceous and starchy components occurs, is not overloaded by the fibrous components and can, therefore, operate more efficiently.



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MILLING OF CEREAL GRAINS AND PROCESSING OF PRODUCTS DERIVED THEREFROM

IMPROVEMENT ON PRIOR PROCESS

This application is an improvement upon the process disclosed in applicant's prior application, Ser. No. 557,030, filed June 13, 1966, entitled "Milling of Cereal Grains and Processing of Products Derived Therefrom," now U.S. Pat. No. 3,519,431, issued July 7, 1970, wherein cereal grains are subjected to wet milling and the components are separated in the presence of a substantially nonaqueous extractive solvent.

BACKGROUND OF THE INVENTION

The process disclosed in my prior application involves subjecting the cereal grain to milling in the presence of a substantially nonaqueous solvent medium so that milling of the germ fraction and bran coat from the grain kernel is effected simultaneously with the extraction of a substantial amount of the fatty content or cereal oil. Following the initial milling operation, the milled grain is separated by subsequent milling, screening, centrifuging and finishing steps, into its fibrous, proteinaceous, starchy and oil components. In said prior process, the final separation of the fibrous, proteinaceous and starchy components is accomplished in a final separation section which includes milling, screening and centrifuging, and substantially all of the fibrous component was directed through such final separation section. It has now been determined that the passage of substantially all of the fibrous component through said separation section overloads said section and interferes with totally efficient separation of all of the components. The objective then is to relieve the final separation section of the excessive fibrous component load.

It is one object of this invention to provide an improvement in the milling of cereal grains and the processing of products derived therefrom, which involves separating a major portion of the fibrous component material from the other components and removing said fibrous component material from the system in advance of the final separation section, whereby the latter is not required to handle the same so that more efficient separation is accomplished and more concentrated, purer final products are produced.

Another object is to provide an improved process wherein the initial milling operation which separates the bran coat from the grain kernel is followed by screening and milling steps which will effectively separate substantially the major portion of the fibrous component so that it may be removed from the system without passing through the final separation section; the process also contemplating screening to separate and remove the fine fractions of said fibrous component which were previously removed from the solvent medium or miscella used in the initial milling and other phases of the process, whereby the final separation section is not required to handle said fine fractions.

Still another object is to provide a process of the character described, in which it is desirable to remove, in the primary extractive milling step, substantial amounts of the fibrous and proteinaceous portions of the grain kernels and by simultaneous extraction also remove substantial amounts of the fatty constituents and thereby yield a more concentrated endosperm fraction, which is either whole or in relatively large broken pieces and which contains most of the starch and the remaining protein; the recovery of the endosperm fraction in this state facilitates the extraction of the fatty substances and, upon subsequent grinding or milling, permits ready separation of residual fiber content, whereby that part of the proteinaceous component or gluten, which is intimately associated with the starchy portions of the endosperm fraction, can be more easily separated in the final separation section of said process to thereby produce purer products.

The improved process disclosed herein is particularly applicable to milling and processing the cereal grains which are physically smaller in size, such as wheat, the small kernel varieties of corn and the sorghum grains which are characterized by the presence of substantial external areas of relatively thick enveloping pericarp and underlying protein cells. When milling the smaller grains in a primary extractive milling step, it is an objective of the present invention to minimize the disintegration of the endosperm fraction while specifically removing the relatively thick pericarp and the layers immediately underlying said pericarp so that a clean separation of the fibrous, proteinaceous, starchy and fatty components, both in said primary milling step and in subsequent screening, milling and centrifuging procedures, may be carried out.

Other objects and advantages of this invention will appear from the detailed description, taken in connection with the drawing which is a flow diagram of an apparatus, constructed in accordance with the invention, for milling cereal grains and processing the products derived from such milling.

The apparatus and process hereinafter described is applicable to the cereal grains from the group comprising wheat, maize or corn, rye and the sorghum grains and is primarily adaptable to the treatment of the cereal grains of smaller physical size. Basically, the process is generally similar to that disclosed in my copending application, Ser. No. 557,030, filed June 13, 1966, in that the primary milling of the grain, as well as the subsequent processing and separation of the grain into its fibrous, proteinaceous, starchy and fatty components, is carried out in the presence of a substantially nonaqueous extractive solvent.

As shown in the drawing, the process includes a primary extractive milling section A wherein the bran coat or pericarp and germ fraction are milled from the endosperm fraction of the grain. From the milling section, the milled grain is conducted to a first-stage separation section, generally identified by the letter B, wherein various screening and grinding operations occur to effect a separation of the components of the grain. From the section B, certain of the components are taken to a second-stage separation section C wherein further screening and grinding operations are carried out, after which the components are directed to a final separation section D. Such final separation section includes multistage screening and centrifuging operations which function to finally separate the fibrous, proteinaceous and starch components of the grain, after which said components are conducted to separate desolventizer systems to produce the independent products from the milled grain.

The primary milling and the subsequent processing of the milled grain is carried out in a volatile liquid organic solvent medium and as the various processing steps are carried out, the miscella will consist of the solvent, the oil or fatty substances which the solvent extracts from the grain, and will also include fine materials which are primarily the bran fractions of the grain including the fibrous component; the fine material will also include some of the proteinaceous and the starchy components. Provision is made in the process to extract from the miscella these fine materials and to return them to the system for final separation. For this purpose, an extraction section E is illustrated and the equipment in this section may be that which is specifically described in my prior copending application above referred to. However, any known extraction system which will remove the fine materials from the oil-containing miscella may be employed at this point in the process.

In my prior process, the materials separated in the extraction section E were taken directly to a mixing tank and a mill or grinder located immediately in advance of the final separation section D. In such case all of the materials, including the fibrous components, separated in section E were passed through the final separation section D. Experience has shown that this results in an overload on the final separation section, which interferes with completely efficient separation of the components. To eliminate this undesirable result, the second-stage separation section C has been added to the system. Additionally, there is a modification in the first-stage separation section B which will be hereinafter described.

Briefly stated, the modification in said first-stage separation section B and the addition of the second-stage separation sec-

tion C to the process effect a removal from the system of a substantial portion of the fibrous component prior to its passage to the final separation section D. This separated and removed fibrous component is directed to the outlet or discharge for the final fibrous components. With this arrangement, the final separation section D is relieved of carrying an excessive load of fibrous component, with the result that said section operates more efficiently to produce purer and more concentrated final products.

Referring specifically to the drawing, the primary milling section A includes an extractive milling machine M having a wet milling section M1, a rinse or washing section M2 and an outlet section M3. The section M1 has a suitable inlet for receiving the grain through an inlet line 10. A pipe 11 supplies a clarified, strong miscella into the inlet end of the milling machine and also to the section M1 and another pipe 11*a* supplies a weaker miscella to the section M2 of said machine.

The solvent in the miscella may be any organic solvent which is effective to extract fatty components from the cereal grain during the milling process, provided the solvent has sufficient volatility that it may be completely removed from the grain products and bran coat at temperatures below that at which the milling products are damaged. Among the preferred solvents are low-boiling, highly refined petroleum fraction, such as n-hexane and n-heptane. In addition to nonpolar solvents of this type, polar solvents, such as alcohols, the lower boiling point ketone and ethers, may be used; as for example, ethanol, isopropanol, acetone, ethyl ether and isopropyl ether. Chlorinated hydrocarbons, as for example, chlorinated ethers, ethylene dichloride and trichloro ethylene may be used, but are not preferred because of their higher boiling points. Mixtures of such solvents, especially mixtures of polar and nonpolar solvents, are specially useful.

Instead of employing a pure, relatively anhydrous solvent, the extraction may be accomplished with a solvent or solvent mixture which will dissolve a smaller proportion of water, preferably to form a constant-boiling azeotrope. An azeotropic solvent is conveniently handled in this process since it tends to provide a constant-boiling, uniform extracting medium containing a small percentage of water which aids in the wetting and penetration of the bran layers, and yet does not contain or substantially impart free water to the hydratable constituents, e.g., starch, sugars, etc., of the inner aleurone layer and the starchy endosperm. Any excess of water picked up from the cereal grain by condensation from air and/or from other sources is lost in an azeotropic distillation step during recovery of the solvent.

The proportion of solvent to grain solids in the process is not critical, but the practicable operating range is from 75 to 150 parts of solvent to 100 parts by weight of grain. The lower proportion is about as low as will allow operations which are in most respects satisfactory, but 100 parts is a more advantageous proportion. The higher proportions above 100 parts are applicable to the higher density solvents such as chlorinated ethers and other higher boiling point solvents.

Any suitable type of extractive milling machine may be employed, as for example the type shown in the above referred to copending application, Ser. No. 557,030. Other types of extractive milling machines which would be usable are described in my prior U.S. Pat. Nos. 3,217,769, 3,165,134, 3,382,904 and 3,401,731. Any of these milling machines may be adapted to the surface milling of cereal grains by suitable modifications of their stators and rotors.

Prior to being conducted through the line 10 into the inlet end of the milling machine, the grain is suitably tempered or conditioned by small moisture additions in the desired manner in order that the bran coat may be properly softened. Any well-known tempering or conditioning method may be employed. Preferably, the initially conditioned or tempered grain is then heated while in contact with one or more bran coat softening agents for a sufficient period of time to expand the cellular structures and to disrupt the cohesion of the heterogeneous components of the grain and thus facilitate the removal of said bran coat when it is subjected to the milling operation in the machine M. Such pretreatment of the whole grain also facilitates the components separations which occur following the subsequent disintegrative milling steps.

One specific objective of this invention is to initially operate the milling machine to minimize breakage of the endosperm fraction of the kernel, while selectively removing as much as possible of the bran coat or pericarp and germ; for this purpose, the milling machine is properly adjusted to the size of the grain being milled. Such adjustment, together with the softening of the outer bran coat layers as above described, results in being able to selectively separate the bran coat and germ fraction from the endosperm fraction with a minimum breakage of the latter.

As the pretreated grain is directed through the inlet and into the milling section M1 of the milling machine M, it is subjected to contact with the clarified, strong miscella, which functions to extract the fatty substances, such as the cereal oil, from the grain. This oil-containing miscella is discharged through a discharge pipe 11*b* and is conducted to the extraction section E of the system. After milling, the grain moves into the rinse or wash section M2 where it is contacted by a weaker miscella to accomplish additional extraction. The oil-containing miscella from section M2 is weaker than that discharging from section M1 and this weaker oil-containing miscella is directed from the machine M through a pipe 12 into a weak miscella tank 13. The solvent-rinsed milled grain moves into the outlet section M3, from which it is discharged through an outlet 14. The outlet conducts the milled grain from the milling machine M to one end of an inclined conveyor 15.

The conveyor 15 is preferably inclined to allow residual rinse solvent to drain back into a solvent and vaportight hopper 15*a* of the conveyor from which, by means of an overflow pipe 16, said solvent joins the stream of rinse solvent flowing through the discharge line 12. It is noted that the rinse solvent so collected from the milling machine M and from the overflow pipe 16 is now sufficiently strengthened with the dissolved oil to comprise the weak miscella which is delivered to the weak miscella tank 13.

The mass of milled grain moves upwardly along the conveyor 15 and is thereby drained of the rinse solvent. It is discharged from the conveyor through a sealed conductor 17 to a vibratory screen 18, where the milled fractions are screened and rinsed with a dilute rinse solvent miscella which is obtained from other points in the overall process (not Shown) and which is delivered through the pipe 19. The underflow from screen 18 which includes the rinsings and the extracted oils and fines which have passed through the relatively coarse screen are conducted by a pipe 20 to the line 12 extending to the weak miscella tank 13. The weak miscella, having certain fractions of fine materials therein, is pumped from the tank 13 by means of a pump 21 and line 22 to the extraction section E of the system. As has been noted, the extraction section is used to separate the bran coat components and also the fine endosperm fragments from the oil-containing miscella.

The washed and screened material, which comprises the whole and larger broken pieces of the endosperm fraction, and the residual fibrous and proteinaceous fractions which were not separated in the milling apparatus M, are conducted from said screen through a discharge 23 to a single runner attrition mill 24; in such mill the material is ground into a thick slurry of particles, it being preferable that grinding be such that most of the particles will pass through a 60- to 80-mesh screen when washed through the screened deck of a vibratory screen 25 to which such particles are next conducted through the discharge pipe 26. The screen 25 is similar in function to the screen 18 and the particles introduced onto the screen thereof are washed by means of a weak miscella supplied through a pipe 27. The underflow from the screen 25 is discharged through conductor 28 to a pump 29, and said pump functions to deliver the material through a line 30 to a

mixing tank 31, such mixing tank being located just in advance of the final separation section D of the system.

The fibrous residue and any endosperm particles which may remain on the screen 25 are conducted from the screen through a discharge chute 32 to a conveyor 33. Such conveyor is preferably inclined so as to drain any solvent from the particles being carried upwardly in the conveyor; the solvent is discharged from the conveyor through a pipe 32*a* which connects with the underflow conductor 28. It might be noted that the underflow from the screen 25 is, in fact, a weak miscella slurry containing the endosperm materials and smaller proportions of the proteinaceous fractions or gluten and fine fiber; it is this material which is delivered directly to the mixing tank 31.

The mixture of fibrous, proteinaceous and starchy components which comprise the bran fractions in the miscella discharged from the milling machine M, as well as that mixture which might remain in the miscella from the screening steps of section B, are conducted with the miscella to the extraction section E. In this section these fractions are extracted and are discharged therefrom through a pipe or discharge line 34. The oil-containing miscella from the extraction section E is conducted through a discharge line 35 to an oil recovery section (not shown) which also clarifies the solvent for recycling into the system.

Since the materials being conducted from the extraction section E contain quantities of fibrous components, these materials are taken to the upper deck section of a vibratory screen 36. The screen deck is preferably a relatively coarse 14- to 20-mesh screen through which the solvent-rinsed proteinaceous components or gluten and the starchy particles pass and are delivered through line 37 to the upper end of the conveyor 33 to commingle with the smaller quantity of fibrous and starchy endosperm fragments, which have been delivered from the screen 25 and which are passing upwardly through said conveyor. A weak miscella is directed to the screen 36 through a suitable line 38.

The coarse fiber from screen 36 is discharged through a conductor 39 which extends to a final discharge conveyor 40, which conducts all of the fibrous component which is separated in the process from the system.

The commingled material at the upper end of the conveyor 33 includes primarily those parts of the starchy components, the proteinaceous material and the fibrous fraction which have not passed through the screen surface of vibratory screen 25. This material is directed to a discharge 41 and into a single or double runner attrition mill 42, or its functional equivalent, where the mass of material is ground to such fineness that the nonfibrous material will all pass through a 100-mesh screen. However, the major portion of the solvent-rinsed fiber will remain on the screen of a vibratory screen unit 43 to which the material is conducted from the mill 42 by means of a conductor 44. Suitable rinse solvent is directed to the screen unit 43 by a pipe 45. The material which traverses the screen, which is substantially a fibrous material, is conducted therefrom through a line 46 to the conveyor 40. The underflow from the screen unit 43 which is predominantly the starchy material with some gluten, is directed through the conductor 47 to the upper end of the mixer tank 31.

It is thus seen that the majority of the material delivered to the mixing tank 31 includes the starch and protein components, although, of course, there is some fibrous material mixed therewith. However, due to the grinding and screening steps which have been carried out in advance of the mixing tank 31, the major portion of the fibrous component has been separated and removed from the system. This eliminates passing the majority of the fibrous component to the final separation section D.

The predominantly starch and gluten slurry in tank 31 is then conducted through line 48 to a final grind in the double-runner closely set attrition mill 49 where it is subjected to the final grinding procedure. From this point the finely ground material is pumped by means of pump 50 to the final separation section D wherein multistage screening and centrifuging is carried out to separate the fibrous, proteinaceous and starch components of the grain. As has been noted, the particular construction of the section D may be that shown in my prior copending application, Ser. No. 557,030; or it may be any suitable screening and centrifuging arrangement which is capable of separating the components which are delivered to the section.

The fibrous component separated in the final separation section D is discharged therefrom through a line 51 to the conveyor 40 which delivers the component to a suitable desolventizer system 52 and from this system the final fiber is discharged through line 53. The proteinaceous component is discharged from section D through line 54, passes through the desolventizer system 55 and the final protein product is recovered through discharge line 56. The starch component is conducted from the final separation section through line 57, through the desolventizer system 58 and the starch product is collected through final discharge line 59.

From the foregoing, it will be seen that the first stage separation section B of the present invention includes the use of a screen immediately following the conveyor 15 so that an early separation of the fibrous material may be carried out. Additionally, the use of the screens and mill in section C assures that the final separation section D will be relieved of an excessive fiber load in the slurry. The improvement may thus be summarized as providing a process and means which effectively separates the major proportion of the coarse fibrous fraction from the extracted proteinaceous and fine starchy materials and directing only minor portions of the fibrous fraction, along with the endosperm and proteinaceous fractions, to the mixing tank 31 which precedes the final grinding, separation and recovery of the various components. This results in better separation in the section D by increasing the centrifugal separator capacity and gives a more complete separation of the starch from the gluten or proteinaceous fractions and the fiber. A higher protein content gluten meal will also result due to the early isolation and removal of most of the crude fiber from the starch-gluten slurry feed to the separators which are used in the complete process.

As heretofore described, the separated fine endosperm materials and bran fractions which are separated in the extraction section E are discharged through the line 34 and conducted to the screen 36. In an alternative procedure, screen 36 may be eliminated by conducting the separated materials from the extraction section E through the conductor shown in dotted lines and marked 34*a* to the discharge line 17 extending from the first conveyor 15. By augmenting the solvent-washing procedures ahead of the screen 18, the extracted, predominantly bran coat material from the extraction section would join the predominantly endosperm material coming from the milling machine M and would then be carried through screen 18, mill 24, screen 25 and conveyor 33 to reach the line 41 extending from said latter conveyor. This modification of the system would still accomplish the basic purpose of separating and removing the main fibrous fractions from the starch and gluten prior to and in advance of the final separator section D to relieve such section of the fiber content load.

The separations, extractions and recovery procedures herein described, and which are subsequent to the primary milling step, may be similarly used as improvements in the general extractive milling process of the applicant's copending application, Ser. No. 557,030, when recovering starch and gluten concentrates from byproduct gluten feeds and meals produced by the conventional water wet milling process; flour and bran from byproduct wheat shorts obtained from the usual roller milling of wheat; and rice flour and a protein concentrate from byproduct rice bran derived from either conventional dry milling of from the applicant's solvent-extractive milling processes for rice which are described in U.S. Pat. Nos. 3,261,690, 3,330,666, 3,421,902 and 3,422,866.

What is claimed is:

1. In a process for milling cereal grains wherein the grain is subjected to a primary controlled milling in the presence of a substantially nonaqueous liquid fat-extractive solvent to effect separation of the bran layer constituents from the endosperm components and separation of the germ fractions from said endosperm components and also wherein the products derived from said milling are thereafter subjected to solvent extraction and separation steps to yield a cereal grain oil and the fibrous, proteinaceous and starchy components of the grain in the final separation stages, the improvement which resides in,

separating the major portion of fibrous component from the other components following the primary milling but in advance of the final separation stages,

recovering said separated portion of the fibrous component,

conducting the unseparated components to the final separation stage to separate the same into the respective starch component, protein component and the minor portion of the fibrous component, and

separately recovering the separated components.

2. In a process for milling and processing cereal grains wherein the grain is subjected to a primary controlled milling operation conducted in the presence of a substantially nonaqueous volatile liquid fat-extractive organic solvent to effect separation of the bran coat and the oily germ fractions from the endosperm fraction and also wherein the milled grain fractions are thereafter subjected to solvent extraction and separation steps to yield a cereal grain oil and the starch, gluten and fibrous components in the final separation stages, the improvement which comprises,

subjecting the milled grain immediately after the milling operation is completed to separation stages and solvent extraction to substantially separate the endosperm and bran fractions,

conducting the endosperm fraction to the final separation stages to separate the starchy, proteinaceous and minor portions of the fibrous components from each other,

subjecting the bran fractions which were separated immediately after the milling operation was completed to further separations to separate the major portion of the fibrous component of the bran fraction, and

recovering said fibrous component without directing it through the final separation stages of the process.

3. In a solvent-extractive milling process for cereal grains wherein the grain is subjected to a primary controlled milling operation in the presence of a volatile liquid fat-extractive organic solvent capable of extracting the fatty components to initially effect a substantial separation between the endosperm fractions and the combined bran coat and oily germ fractions and also wherein the endosperm fraction is ultimately subjected to final separation procedures in the presence of said solvent to separate a preponderantly starchy endosperm component from any residual bran coat fractions, the improvement which comprises,

following the primary milling step with additional separation steps to further separate from the bran fractions the endosperm fractions which are conducted to said final separation procedure,

subjecting the separated bran fractions to an extraction and grinding step to separate and remove therefrom any residual endosperm fractions, and

combining the separated residual endosperm fractions with the previously separated endosperm fractions prior to the latter being conducted to the final separating procedures.

4. The improvement as set forth in claim 3, with the additional step of

independently recovering the separated bran fractions, whereby such fractions are not subjected to the final separation procedure of the process.

5. The improvement as set forth in claim 3 wherein the cereal grains are selected from the group consisting of wheat, maize, rye and the sorghum grains.

6. The improvement as set forth in claim 3, wherein the additional separation steps and the step of subjecting the bran fractions to extraction and grinding comprise,

subjecting the fractions discharged from the milling operation to a first-stage screening and solvent extraction,

conducting the material which traverses the screen of said first-stage screening to a grinding operation and thereafter to a second-stage screening and solvent extraction,

conducting the material which traverses the screen of second-stage screening to a second grinding operation and thereafter to a third-stage screening and solvent extraction,

directing the underflow from said second and third stage screenings to the final separation stage of the process, and

independently recovering from the third-stage screening the predominantly fibrous material which has traversed the screen of said third-stage screening.

7. The improvement as set forth in claim 6, together with the additional steps of,

conducting the oil-containing solvent having bran coat and endosperm fractions therein from the primary milling operation and from the first-stage screening,

extracting the bran coat and endosperm fractions from the solvent,

subjecting the extracted fractions to screening and solvent extraction to separate the major portion of the fibrous component,

separately recovering said fibrous component, and

conducting the remaining fractions to the final separation stage of the process.

8. The improvement as set forth in claim 6, wherein the cereal grains are selected from the group consisting of wheat, maize, rye and the sorghum grains.

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