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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Rice Milling

I, TRUMAN BENJAMIN WAYNE, of 2405 Norfolk Street, Houston 6, Texas, United States of America, a citizen of the United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a process for the treatment of brown rice and to apparatus for carrying out the process.

It is common practice to prepare brown rice for further milling by cleaning dirt, straw and other debris from rough, or paddy, rice which is then sent to stone hullers where hulls are removed, together with some loosely adhering bran. The hulled, brown rice is then commonly milled in a machine comprising a horizontal cylindrical shell having perforations there-through. The machine has a rapidly revolving inner rotor with a ribbed surface which rubs the brown rice against the outer cylindrical shell to abrade bran from the endosperm.

The surface-grinding operation is normally carried out under retention time and feed-rate conditions selected to produce a desired degree of removal of the outer bran layers from the rice kernels. The milling process is rather severe, and breaks a substantial proportion of the whole rice grains into two or more fragments by a combination of factors such as impact, mechanical and thermal stresses, and generated heat. Breakage results in economic loss, since broken rice has a lower market value than whole rice grains.

As one aspect of the present invention there is provided a process for the treatment of brown rice, wherein the rice is subjected to milling in the presence of a volatile liquid organic solvent in order to remove the bran layers from the exterior of the kernels of the rice while simultaneously extracting a substantial part of the fatty and colouring components (including oil) from the bran and milled rice.

According to a second aspect of the inven-

tion there is provided apparatus for the treatment of brown rice, comprising a mill, means for feeding brown rice into the mill, means to receive mixed bran and rice from the mill, and means for passing a stream of a solvent effective to extract fatty components (including oil) and colouring matter from rice through the mill in contact with rice being milled.

The brown rice starting material may be hulled and cleaned rough or paddy rice, or rough or paddy rice which has been parboiled and dried prior to removal of the hulls. Either source of brown rice is satisfactory although that derived from rough or paddy rice yields a better product than that derived from brown rice which has been sufficiently parboiled to drive much of the bran layer into the endosperm.

Solvent extractive milling may be used alone or combined with softening of the bran layers prior to milling by means of a softener which does not contain water in an amount which will penetrate into the starchy endosperm and damage the brown rice kernels.

The use of a liquid-bran coat softening agent is described in more detail in the specification of my copending divisional application No. 53199/66 (Serial No. 1,066,947). The preferred temperature for carrying out the bran-layer softening during a holding period is from 32°C to 60°C.

The bran-softening agents may conveniently be materials which are soluble in the solvent or which are capable of being emulsified into the solvent in contradistinction to being truly soluble therein. These materials usually tend to selectively wet and to be absorbed by the bran coating. Such solutions or suspensions however should be limited in the quantity used to proportions insufficient to penetrate through the bran coating and thereby to wet, swell or discolor the endosperm so that the water-wettable or water-soluble softening agent and the water in which it is dissolved or suspended will be absorbed in the bran layer to the sub-

stantial exclusion of absorption below the aleurone layer.

Recycled rice oil or a solution of rice oil in a suitable solvent is a very satisfactory softening agent, and is preferred since it is readily available at substantially no cost.

When a bran-coat softening agent is used it should be used in proportions of about 0.25 to 5.0 weight per cent, based on the weight of the brown rice. These quantities apply to the total liquid bran-softening agent, including any medium in which a bran-softener is dissolved in order to obtain proper distribution and wetting of the rice. When an undiluted mineral oil or vegetable oil is used, the quantity of oil required is in the range from about 0.25 to 1.0 per cent; while from 2.0 to 5.0 per cent of a solution of the same oil in a suitable solvent may be desirable, according to the degree of dilution. Thus, for recycled rice oil, this range of 2.0 to 5.0 per cent would apply to the oil plus residual solvent content.

In many practical applications it is desirable to extract certain water-soluble components of the brown rice, such as chlorophyll, anthocyanins or other colouring matters from the rice together with the fatty components.

Solvent extractive milling may be performed in a single mill or in mills arranged in series, roughly corresponding to the arrangement of mills in "first-break" and "second-break" milling of conventional processes.

It is often desirable to use a series of extraction steps, only one of which is extraction during the milling operation. For example, in one practical application of this process, brown rice after the de-hulling operation is treated with a softening agent in a quantity and for a time sufficient to soften and loosen the bran coating on the rice kernels. The softening agent in this case advantageously may be recycled rice oil or rice oil containing a solvent. Bran is milled from the rice kernels in the presence of the softening agent and a stream of solvent containing dissolved rice oil is passed through the mill in contact with the rice.

In one particular application of the process, rice and bran are withdrawn together from the mill to additional extraction steps which may be conducted in an extractor of the moving basket type or of any other type which permits concurrent and/or countercurrent flow of solvent through the rice and bran issuing from the mill. An effluent of solvent containing fatty components and colouring matters extracted during the milling step is withdrawn from the mill and is again passed through the bran and rice, preferably in countercurrent direction, thus extracting additional fatty components and colouring matter from the rice and bran, and becoming more concentrated in fatty components. At least a part of the resulting concentrated solvent-fatty component solution is withdrawn to a solvent-recovery system where solvent is separated from rice oil and solvent

is returned to the system. Solvent containing fatty components of rice is hereinafter referred to as "miscella".

The returned fresh solvent is passed in counter-current to the rice and bran from the previous extraction step, thus substantially-completely removing all residual strong miscella and fatty components left in the material. The rice and bran mixture is then passed to steps in which residual solvent is evaporated from the rice, preferably by use of moderate heat and agitation, the desolventized rice and bran are separated, and the rice is then subjected to any polishing or coating steps that may be desired.

The fresh solvent after passing through the rice and bran in countercurrent flow will contain some rice oil and in this state is called "weak miscella". The weak miscella may be combined with a part of the strong miscella which has passed in countercurrent flow with the rice and bran immediately after withdrawal of the rice and bran from the mill and the resulting miscella is then passed through the mill to serve as extractive solvent during the milling operation.

In another practical application of this process, bran on the brown rice is softened and is milled in the presence of the softening agent and a stream of solvent passing through the mill in contact with the rice. Rice is fed into the mill at a selected rate and a selected back pressure is applied upon rice passing through the mill to give the desired degree of abrasion required for any particular degree of bran removal.

In this application the stream of solvent passed through the mill is strong miscella containing oil extracted from the bran and germ in later extraction steps. The flow of solvent and rice is preferably, although not necessarily, countercurrent throughout the operation. Bran is abraded from the rice in the mill by rubbing the rice against a screen having openings there-through and by friction of the grains against each other and the stream of strong miscella flows not only through the rice but along the outside of the screen and carries away bran passing through the screen. A large proportion of the bran is thus separated from the rice in the mill.

The rice and residual bran contained therein is then passed to an extractor-separator where it is again extracted with a weaker miscella. This extractor-separator preferably is a vertical tank, and rice and miscella are agitated sufficiently strongly therein that all remaining loosely adherent bran is washed from the rice by miscella and is carried through a screen or other separating device. This operation is preferably conducted by introducing rice at the top of the tank so that it settles downward through the swirling liquid. Rice now free from bran is withdrawn from the extraction-separation tank, is passed to a desolventizer, and

preferably is passed through two additional extraction steps in route. In the first of these extraction steps, the rice is washed with a very dilute miscella and in the second step the rice is washed with fresh solvent to remove all traces of oil and miscella.

In the desolventizer rice is agitated and mildly heated to evaporate solvent from the rice. All vapours from all extraction steps are passed to a solvent-recovery system. Bran and solvent from the extraction-separation tank are passed to a weak miscella settling tank where bran settles in the bottom of the tank to form a slurry. This slurry is then passed to a strong miscella settling tank where it is combined with an effluent of strong miscella containing bran issuing from the mill and is further settled to form a concentrated bran slurry. Concentrated bran slurry is passed through a filter, preferably of rotary type, and a resulting bran cake on the filter is washed first with clarified weak miscella from the weak miscella settling tank and receives a final washing with substantially fresh solvent from the last rice-washing step, thus further extracting fatty components and colouring matter from the bran. Bran from the filter cake is then passed to a drier and dried while strong miscella from the filter is passed to oil separation and solvent recovery steps where rice oil is separated from the solvent and fresh solvent is recycled to the last bran-washing step.

When maximum oil recovery is desired, hulls and bran separated in the hulling step may be combined with the brown rice feed to the milling step. Also, when it is desired that the degree of milling accomplished in the mill be reduced to leave a part of the bran layers on the rice, the current of strong miscella passed through the mill in contact with the rice will soften the bran layers sufficiently to permit the required degree of milling without undue breakage of kernels; the strong miscella in this case serving both as bran-softening agent and as solvent, as the strong miscella is relatively rich in rice oil at this stage of the extraction process. Retention of a part of the inner bran layers including the aleurone layer increases the protein and mineral contents of the milled rice.

Rice and bran treated by the process are substantially fat free, have good keeping qualities, are sterile and free from insects and insect eggs. The rice has good cooking qualities, colour, taste and physical appearance. The recovered rice oil is light in colour, low in acidity and is easily refined to an edible oil.

The solvent has additional advantages in that it maintains the bran in a wet and hence increasingly soft condition during the milling operation, acts as a flushing medium for washing separated bran from the rice, and washes openings in screens and other parts of the apparatus free from bran, and acts as a coolant during the milling operation, thus effectively

preventing build up of temperature due to friction and preventing heat checking of the rice.

Solvents which can be used for extractive milling include petroleum fractions such as n-hexane, n-heptane, alcohols, such as ethanol or isopropanol, which may contain a relatively small proportion of dissolved water, or a mixture of nonpolar solvents such as an alcohol-ether mixture. Chlorinated hydrocarbons such as ethylene dichloride, trichloroethylene, tetrachloroethylene and chlorinated ethers such as dichlorodiethylether also may be used. Such solvents and solvent mixtures may be constant boiling azeotropes containing water or they may be anhydrous when introduced into the system and become azeotropic by absorption of water. When an excess of water is present in the solvent, provision will be made in the solvent recovery system for separating excess water from the solvent in a manner known per se.

All of the above solvents not only extract fatty compounds from the rice bran and germ but inhibit the action of oxidases, lipases and possibly other enzymic materials and extract certain colouring matters, such as chlorophyll and anthocyanins from the rice. The improved quality of the rice products is an effect of this enzyme inhibition and extraction and of sterilization effected by the solvent. Apparently there is no noticeable enzymic action when solvent extraction is used and thus the rice oil has improved quality, better colour and lower acidity as compared to that obtained by extracting after milling.

It will readily be seen that extractive milling will require apparatus differing from the types hitherto readily available upon the market. Apparatus for extractive milling comprises means for passing a stream of solvent through the mill in contact with the rice. Means are provided for feeding rice into the mill and the mill itself may be provided with means for exerting a selected degree of back pressure upon the rice during its passage. Thus rice is simultaneously extracted and milled in its course through one or more mills.

Particular embodiments, by way of example, of apparatus according to the invention are hereinafter described with reference to the accompanying drawings in which:—

Figures 1 and 2 show a first embodiment of apparatus according to the invention:

Figures 3 and 4 show a second embodiment:

Figure 5 shows a further embodiment incorporating the apparatus of Figures 1 and 2, and

Figure 6 shows another embodiment.

One apparatus of preferred type is shown in the attached Figs. 1 and 2 wherein reference number 1 designates generally an assembly consisting of three substantially similar units of a horizontal milling apparatus together with a tandem variable speed drive. The three units are arranged in series and each has an inlet

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2, an outlet 3, a cylindrical housing 4, a perforated cylindrical metal member, or screen, 5, laterally spaced from the housing, and a central rotor 6 within the screen.

5 Each unit in the series is substantially identical with the exception that the hand of short helically arranged flights 7 on the horizontal rotor 6 in the central unit is opposite that of the flights on the two other units. A helical ribbon 8 is arranged between the housing and the screen and is attached to the housing at a selected spacing from the housing to support the screen 5 rigidly at a selected distance from the housing and to provide a helical path for liquid flowing through the unit between the screen and housing.

The housings are equipped with piping connections 16, 17, 18 and 19 for liquid so that a stream of solvent can be sent through the unit, either concurrently or countercurrently to the movement of rice therethrough.

The screen 5 preferably is fabricated of a perforated metal or heavy wire mesh cloth which has perforations or open meshes of area too small to allow a rice grain to pass through. The screen, due to the openings, presents a roughened surface, suitable to abrade bran from the rice and through which the stream of solvent will pass freely. The texture of the perforated or wire cloth surface may be varied to suit the degree of milling in each successive unit. Thus, the first unit may make a coarse cut into the bran layer and the others may make successive finer cuts which tend to polish the milled rice grains. Rectangular or oblong openings are preferred since openings of this shape reduce breakage of rice kernels due to a pointed end of a kernel becoming caught in an opening.

40 The helical flights 7 preferably overlap each other by about one half of the arc on the surface of the rotor covered by a corresponding flight in a succeeding group of flights. The rotor 6 is supported in bearings 9 and 10 at the ends thereof and is driven by any suitable drive illustrated as a series of sprockets and chains driven by a motor 11 through a reducing gear assembly 12. Each of the units is provided with an inlet 2 arranged to introduce rice upon the surface of the rotor 6 between the rotor and perforated screen 5. A means for exerting back pressure on the rice is provided and may take a number of forms. For instance, the pitch of the helical flights 7 on the last unit of the series may be somewhat smaller than the pitch in preceding units or the pitch may be gradually decreased from that of the first unit through the second unit to the third unit. Too much decrease in pitch however should be avoided as this would cause the mill to jam. Alternatively the pitch of helical flights 7 may be the same on all rotors and the drive may be arranged to drive a succeeding unit at lesser speed. Variable speed sheaves 13 and 14 and a V-belt 15 illustrate

one type of variable drive of this type. In any case, the helical flights of a succeeding unit and the drive means cooperate to exert a selected degree of back pressure on rice in a preceding unit.

A liquid solvent is introduced into a unit of the series and may be passed therethrough either concurrently or countercurrently to the direction of flow of the rice in the mill. It is preferred that solvent be introduced into each of the units successively and passed in countercurrent flow through all units. The arrangement illustrated is effective to pass solvent in countercurrent flow through each of the mills consecutively, and then on to succeeding steps for separation of bran, further extraction of the rice and bran, and recovery of solvent and separation of rice oil as described both above and hereinbelow.

Another type of milling device is shown in Figs. 3 and 4. In Fig. 3 the reference number 20 shows a hopper superimposed on a milling section designated generally as 21, which discharges by means of a chute 22 into a helicoid screw conveyor 24. This screw conveyor consists of an outer tubular casing 23, a helicoid screw 25, a discharge chute 26, a drive means illustrated as a sprocket 27 driven by a motor 28 through a reducing gear 28a. The mill is driven by a suitable drive means, illustrated as a variable speed motor 29 arranged to drive a central frusto-conical rotor 30 through a reducing gear 29a and drive shaft 34. This rotor is located concentrically within a frusto-conical perforated screen 31 which may be formed of perforated metal or a suitable wire screen.

The rotor has spiral flights 32 upon its surface arranged so that when the motor is driven the spiral flights oppose passage of rice downward through the mill and direct the rice strongly outwardly against the inside of the perforated screen. Rice is fed downward within the perforated screen outside the rotor and leaves through an opening 33 surrounding the central drive shaft 34. The frusto-conical rotor 30 also is provided, on its base, with a number of scraper ribs 35 (best shown in Fig. 4) which at the periphery of the cone coincide with the lower end of spiral flights 32. These scraper ribs rotate at substantially the same clearances over a horizontal screen 36 as that between the rotor and the perforated screen 31 so that they tend to sweep the rice from the bottom of the screen into the central opening 33. It is preferred that the frusto-conical rotor be adjustable vertically upon the drive shaft 34 by means of set screws 34a or other adjustable means. Considerable vertical movement is required to effect small changes in the width of the annulus between the perforated screen 31 and the rotor 30 and the set screws thus form a convenient means of accurately adjusting this annulus to the type of grain being milled.

A means for passing a current of liquid sol-

vent through a housing 37 and screen 31 into contact with rice in an annular space between rotor 30 and screen 31 is provided, and is illustrated as a pump 38 connected to withdraw clarified miscella from an upper part of a settling tank 39 through a filter 40 and to introduce the withdrawn miscella through line 41 into the interior of the housing 37.

Recycled miscella after passing in counter-current flow to rice in the mill is withdrawn through filter 42 and line 43 to settling tank 39. Alternatively, a connection to line 43 may be made through the pipe connection 43a, illustrated as plugged, and the miscella returned to settling tank 39 from this point. Recycle is thus provided and a side stream may be taken off through line 44 and passed to a solvent recovery system arranged to separate oil, and any excess water that may be present, from the solvent or to any extraction step in the process where it may be useful.

A slurry of concentrated miscella and bran is withdrawn from the bottom of settling tank 39 and passed by lines 45, 46 and 46a to wash a mixture of rice and bran issuing from the mill in a lower part of the helicoid screw conveyor 24. A side stream of this slurry also may be passed through line 46 into an upper part of hopper 20 to serve as bran softening agent. A second side stream of the concentrated miscella carrying bran in suspension is passed by line 47 to bran separation and solvent recovery or to any other extraction desired. The maximum concentration of oil in the strong miscella is preferably maintained at not more than 10% by weight oil so that it has good extractive properties.

Bran passing through openings in screen 31 settles in housing 37 and passes through the openings 48 in a horizontal plate 49 in the mill so that rice and bran are withdrawn from the mill without separation and enter the screw conveyor 24. A weaker miscella from a later extraction step, or fresh solvent from the solvent recovery system is introduced into an upper part of screw conveyor 24 by line 50 so that the mixture of rice and bran withdrawn from the mill receives a two-stage counter-current washing in conveyor 24. It is to be understood that the screw conveyor 24, extends upward for a sufficient distance, indicated by a break in the drawing, that the line 50 connects with the conveyor at a point somewhat above the level of filter 42 so that solvent introduced through line 50 will flow downward through the conveyor. The rice and bran are then passed through discharge chute 26 to any extraction, separation and finishing steps desired.

The level of miscella in conveyor 24 is controlled by valve 51 in drain pipe 52 in which is interstred strainer 53 which contains a coarse perforated screen which is capable of holding back the rice but allows the solvent and finer bran particles to flow into settling tank 39.

Fig. 5 shows another arrangement of ap-

paratus suitable for carrying out extractive milling. A feed hopper 51a is arranged to discharge brown rice into a mixing conveyor 52a into which a liquid bran-softening agent is introduced in desired proportion through a line 53¹ or 53a. From the conveyor 52a the rice containing bran-softening agent is discharged into a ribbon mixer 54 and after thorough mixing therein is passed into a mill designated generally as A and which preferably is constructed as described under Fig. 1 as illustrated, or according to Fig. 3 above.

From the outlet of mill A rice containing residual bran is passed into an elevator 55 and is there washed while passing through the elevator by a miscella of moderate strength entering by line 56. The rice and bran mixture then passes into a separator-extractor tank 57, having motor driven agitator paddles 58 and 58a, and which is fed with weak miscella introduced from line 61 into a discharge elevator 60 and screw feeder 63. Flow of rice is thus counter-current to the flow of liquid in the elevator, screw-feeder, and separator tank 57. The heavier rice sinks through the liquid and is withdrawn by the screw feeder 63 and discharged therefrom into the elevator 60.

Bran suspended in the miscella is withdrawn through a screen 59 and line 64 and passed to a settling tank 65 from which a slurry of bran and miscella is passed to a second settling tank 66. A slurry of bran in strong miscella is withdrawn from tank 66 and passed to a filter 67, illustrated as of rotary type, and is washed on the filter first with a weaker miscella carried by line 68 and finally by an almost fresh solvent carried by line 69. These washing operations leave the bran substantially oil free and it is then passed to a bran drier by means of an elevator 70. The bran drier may be of any type desired, although that illustrated is of rotating tray type. From the bran drier bran is withdrawn through discharge spout 71 into elevator 72 and is passed to any bagging or finishing steps desired.

Rice free from bran is discharged by elevator 60 into an inclined screw conveyor 73 and is there subjected to a final washing by fresh solvent from the solvent-recovery system entering by lines 74 and 74a. Washed rice is delivered by conveyor 73 to surge tank 90, and thence to a desolventizer 92. This desolventizer may be of any type desired as, for example, a tumbler arranged to tumble rice in a current of superheated solvent vapor and/or warm inert gas. From the desolventizer rice is withdrawn at 93 and may be sent to storage, bagging operations or to any finishing steps desired. Clarified strong miscella from an upper middle part of settling tank 66 is withdrawn by pump 78 and is introduced into the mill A by lines 79 and 80, thus providing solvent for extraction during the milling step. The oil content of the strong miscella is maintained sufficiently low that it has good extractive

properties by continual withdrawal of strong miscella from the bottom of the settling tank 66 and the introduction of weaker miscella from tank 65.

5 Vapours from all apparatus illustrated are sent to a solvent-recovery system indicated at 76 and strong miscella from the filter-receiving tank 75 is sent by line 77 to this system. The solvent-recovery system may be of any type
10 desired so long as it provides for the separation of rice oil from solvent and the separation of any excess water that may be present in the system. The solvent recovery system indicated at 76 includes means for condensation of solvent vapours received through lines 82, 83 and 84 and means for separating solvent from rice oil received through line 77 and means for separating excess water from the solvent and to discharge water as indicated at line 85. The solvent and oil recovery system is not illustrated in detail since it is merely an arrangement of apparatus known per se and in itself forms no part of this invention. A container 86 is connected to receive fresh purified solvent
25 from the solvent-recovery system and to return the fresh solvent to the extraction system through line 74. A container 87 and pump 81 also are connected to receive rice oil from the recovery system and may be connected to line 30 53a by valved line 88 for recycle of rice oil as bran-softening agent to mixing conveyor 52a. Alternatively, rice oil containing residual solvent may be withdrawn from the solvent-recovery system by line 89 and recycled to line 35 53a. Valved line 88a is provided for pumping rice oil to storage.

In the embodiment illustrated in Fig. 6 rice from holding tank F1 which has undergone softening treatment in preceding apparatus previously described for Figs. 3 and 5 is delivered by means of screw-feeder 110 and/or 110a into the corresponding combination solvent extraction and milling apparatus G1 and/or G2. If the combination solvent extraction and milling apparatuses G1 and G2 are operated in parallel, both screw feeders are operated. If operated in series, only screw feeder 110a is operated. The helicoid screw flight in the inoperative screw feeder 110 effectively seals off the flow of rice into apparatus G1 and also prevents loss of solvent vapours from the extraction and milling apparatus. A screw feeder 110b receives the material from G2 and conveys it to above the flap gate 111a which determines whether milled rice and bran from apparatus G2 shall directly to inclined conveyor H1 through chute 111c, and thus are products of single stage milling, or whether the milled products from apparatus G2 will be diverted through chute 111b to apparatus G1 to receive a second stage milling. These procedures may roughly be compared to "first break" and "second break" milling in the conventional dry milling process.

65 The construction and operational features of

combination solvent extraction and milling apparatus G1 and G2 are identical, in which, 112 is an outer metal shell which serves as a housing for the apparatus, 113 is an inclined hopper bottom of perforated metal or wire screen construction, 115 is a feed screw which delivers rice from the hopper area formed by shell 112 and inclined bottom 113, 116 is a perforated metal or wire screen stator in which ribbed rotor 117 revolves. The stator and rotor are either cylindrical or frusto-conical shaped, and the ribs on the rotor may either be arranged vertically or diagonally with reference to the vertical dimension of the rotor, and are positioned 45° to 90° apart around the circumference of the rotor. The aperture between the rotor and perforated stator is adjustable by raising or lowering the position of the rotor on its shaft in any suitable manner, while maintaining the stator in fixed position. It is, of course, possible to employ an apparatus in which the position of the rotor is fixed and that of the stator may be varied upward or downward to vary the clearance between them within a range of between one quarter and three quarters of one inch. Closer clearances will tend to increase the milling action but will limit the throughput, whereas the reverse is true where wider clearances are employed.

The discharge from pump 18a is piped so that by closing valve V5 and opening valve V6, the weak miscella from tank compartment 17a may be used in the primary extraction stage. Also, by opening valve V7 when valve V5 remains closed the weak miscella from pump 128 may be sent through pipe 20a to an intermediate extraction stage in a conventional moving basket extractor.

Concurrently with the introduction of unmilled brown rice, or partially milled rice where series milling employing two combination solvent extraction and milling apparatus is practised, a solvent capable of extracting fats and coloring matters from the bran layers and millings therefrom is introduced through pipe 134. The solvent may be fresh solvent from the solvent recovery and oil recovery steps previously described, but is usually under multiple extraction procedure a weak miscella withdrawn from a chamber 17a in a lower part of a conventional moving basket extractor. In the instance weak miscella from pump 18a is delivered through pipe 134 to apparatus G1 and/or G2 through valves V3 and/or V4; respectively, to inlet connection 114 or 114c and circulates countercurrently upwards through the descending column of rice and millings between rotor 117 and stator 116 and discharges through outlet connection 114a or 114b. Rotor 117 is driven at r.p.m. speeds selected over a substantial range by a motor and speed reducer drive 120. Smaller apparatus will require higher r.p.m. than larger apparatus to obtain equivalent milling and product throughput for any given clearance between stator and rotor,

as it is largely a matter of rim speed expressed in feet per second. However, excessive rim speeds above the actual milling requirements will result in excessive breakage of rice grains. Applicant's speed range expressed as r.p.m. may vary from about 600 r.p.m. for 18 inch average diameter rotor down to 200 r.p.m. for a 60 inch average diameter rotor where a high degree of milling is desired. Slower speeds are used where undermilling is desired. If higher pressures are applied within the stator-rotor aperture by higher grain levels in hoppers and chutes above the rotor, or if positive feed-in is provided, the above stated speeds may be further reduced. In general, the use of solvent extraction simultaneously with milling increases the ease of bran layer removal, and satisfactory milling may be accomplished at lower speeds and under lower pressures against the milling screen than with conventional dry milling procedures.

Whether the flow of solvent through the milling apparatus is concurrent or countercurrent is not critical if further extraction steps in other apparatus will follow. Thus, the flow from pipe 134 may be introduced through connection 114a and exit through connection 114 instead of in the reverse direction.

The mixture of milled rice and bran layer millings falls into lower hopper 118 where it is conveyed out of the apparatus by screw conveyor 119 and enters inclined screw conveyor H1 through chute 121. The solids are conveyed upward by the screw 131 and discharged into screw feeder J1, and from thence into an upper part of a conventional moving basket extractor as indicated at 15, whereas the solvent containing extracted oils and colouring matters drains continuously to miscella settling tank I1 through rotary strainer 122 and pipe 123. Pipe 123a and valve V1 may also serve as a means of draining oil-containing solvent to tank I1, but normally are used only for drainage of the system.

The weak miscella derived as above described, passes through miscella settling tank I1 where most of its bran is settled out and removed through a sludge valve V2 which may be either manually operated or automatically operated by a sludge density controller (not shown). If intermittently operated, pump 132, of a positive displacement diaphragm type, should be coordinated to operate only when valve V2 is open and admits sludge to pipe 130. The sludge discharged by pump 132 enters pipe 133 and discharges into inclined screw conveyor H1 at a point slightly above the liquid level in the system. The weak miscella drains out and the drained sludge joins the milled rice and bran mixture which discharges into screw conveyor J1. The main volume of weak miscella goes down the centre baffle, shown dotted at the right of I1, rises through the staggered baffles, shown dotted at the left of I1, and exits through filter 125 and

pipe 126 into miscella surge tank 127. Pump 128 then sends the weak miscella through pipe 129 to line 20a from which it is supplied to moving basket type extractor. It is then employed in the intermediate extraction step which is conducted in the concurrent flow pattern previously described. The strong miscella produced in this second stage extraction collects in chamber 17b and is then sent to the oil and solvent recovery system previously described, and the milled rice and bran mixture then undergoes the final extraction and rinsing stage as the baskets ascend in countercurrent flow to the fresh solvent stream above chamber 17a. The extracted solids then are discharged to a screw conveyor similar to conveyor 23 of Fig. 3, and enter a desolventizer similar to the desolventiser 92 of Fig. 5 and proceed throughout the remaining steps as previously described.

Equivalents of equipments shown in the process are contemplated. For example, other versions of horizontal and vertical milling machines may be employed. Likewise, instead of conducting secondary extraction and bran solids recovery steps in screw conveyors and rotary filters, multiple extraction steps may be conducted in a series of settlers, in bowl-type centrifuges, or by combining settlers with centrifuges. Instead of a rotary tray desolventizer for bran, rotary drum or fluidized solids systems may be employed. Rice may be desolventized in a moving bed in a vertical column or in a fluidized solids system instead of the rotary drum shown in Fig. 5.

WHAT I CLAIM IS:—

1. A process for the treatment of brown rice, wherein the rice is subjected to milling in the presence of a volatile liquid organic solvent in order to remove the bran layers from the exterior of the kernels of the rice while simultaneously extracting a substantial part of the fatty, and colouring components (including oil) from the bran and milled rice.

2. A process according to Claim 1, wherein the bran layers are softened before milling by means of a softener which does not contain water in an amount which will penetrate into the starchy endosperm and damage the brown rice kernels.

3. A process according to Claim 2, wherein from 0.25 to 5% of a liquid bran softening agent, based on the weight of the brown rice, is mixed with the brown rice before the milling step, and the resulting mixture is held for a time sufficient for the bran of the rice kernels to become softened and loosened before the milling is begun.

4. A process according to Claim 3, wherein the rice and liquid bran-softening agent are maintained at a temperature in the range from about 32°C. to 60°C. during the holding period.

5. A process according to any preceding claim, wherein bran is milled from the exterior



as it is largely a matter of rim speed expressed in feet per second. However, excessive rim speeds above the actual milling requirements will result in excessive breakage of rice grains.

5 Applicant's speed range expressed as r.p.m. may vary from about 600 r.p.m. for 18 inch average diameter rotor down to 200 r.p.m. for a 60 inch average diameter rotor where a high degree of milling is desired. Slower speeds are used where undermilling is desired. If higher pressures are applied within the stator-rotor aperture by higher grain levels in hoppers and chutes above the rotor, or if positive feed-in is provided, the above stated speeds may be further reduced. In general, the use of solvent extraction simultaneously with milling increases the ease of bran layer removal, and satisfactory milling may be accomplished at lower speeds and under lower pressures against the milling screen than with conventional dry milling procedures.

10 Whether the flow of solvent through the milling apparatus is concurrent or countercurrent is not critical if further extraction steps in other apparatus will follow. Thus, the flow from pipe 134 may be introduced through connection 114a and exit through connection 114 instead of in the reverse direction.

15 The mixture of milled rice and bran layer millings falls into lower hopper 118 where it is conveyed out of the apparatus by screw conveyor 119 and enters inclined screw conveyor H1 through chute 121. The solids are conveyed upward by the screw 131 and discharged into screw feeder J1, and from thence into an upper part of a conventional moving basket extractor as indicated at 15, whereas the solvent containing extracted oils and colouring matters drains continuously to miscella settling tank I1 through rotary strainer 122 and pipe 123. Pipe 123a and valve V1 may also serve as a means of draining oil-containing solvent to tank I1, but normally are used only for drainage of the system.

20 The weak miscella derived as above described, passes through miscella settling tank I1 where most of its bran is settled out and removed through a sludge valve V2 which may be either manually operated or automatically operated by a sludge density controller (not shown). If intermittently operated, pump 132, of a positive displacement diaphragm type, should be coordinated to operate only when valve V2 is open and admits sludge to pipe 130. The sludge discharged by pump 132 enters pipe 133 and discharges into inclined screw conveyor H1 at a point slightly above the liquid level in the system. The weak miscella drains out and the drained sludge joins the milled rice and bran mixture which discharges into screw conveyor J1. The main volume of weak miscella goes down the centre baffle, shown dotted at the right of I1, rises through the staggered baffles, shown dotted at the left of I1, and exits through filter 125 and

pipe 126 into miscella surge tank 127. Pump 128 then sends the weak miscella through pipe 129 to line 20a from which it is supplied to moving basket type extractor. It is then employed in the intermediate extraction step which is conducted in the concurrent flow pattern previously described. The strong miscella produced in this second stage extraction collects in chamber 17b and is then sent to the oil and solvent recovery system previously described, and the milled rice and bran mixture then undergoes the final extraction and rinsing stage as the baskets ascend in countercurrent flow to the fresh solvent stream above chamber 17a. The extracted solids then are discharged to a screw conveyor similar to conveyor 23 of Fig. 3. and enter a desolventizer similar to the desolventiser 92 of Fig. 5 and proceed throughout the remaining steps as previously described.

Equivalents of equipments shown in the process are contemplated. For example, other versions of horizontal and vertical milling machines may be employed. Likewise, instead of conducting secondary extraction and bran solids recovery steps in screw conveyors and rotary filters, multiple extraction steps may be conducted in a series of settlers, in bowl-type centrifuges, or by combining settlers with centrifuges. Instead of a rotary tray desolventizer for bran, rotary drum or fluidized solids systems may be employed. Rice may be desolventized in a moving bed in a vertical column or in a fluidized solids system instead of the rotary drum shown in Fig. 5.

WHAT I CLAIM IS:—

1. A process for the treatment of brown rice, wherein the rice is subjected to milling in the presence of a volatile liquid organic solvent in order to remove the bran layers from the exterior of the kernels of the rice while simultaneously extracting a substantial part of the fatty, and colouring components (including oil) from the bran and milled rice.

2. A process according to Claim 1, wherein the bran layers are softened before milling by means of a softener which does not contain water in an amount which will penetrate into the starchy endosperm and damage the brown rice kernels.

3. A process according to Claim 2, wherein from 0.25 to 5% of a liquid bran softening agent, based on the weight of the brown rice, is mixed with the brown rice before the milling step, and the resulting mixture is held for a time sufficient for the bran of the rice kernels to become softened and loosened before the milling is begun.

4. A process according to Claim 3, wherein the rice and liquid bran-softening agent are maintained at a temperature in the range from about 32°C. to 60°C. during the holding period.

5. A process according to any preceding claim, wherein bran is milled from the exterior

of the kernels in the presence of a stream of the liquid organic solvent effective to extract a substantial part of fatty components and colouring matter from the bran and milled rice; both the milled rice and the bran are subjected to an additional extraction process with the solvent after the bran and milled rice are withdrawn from the milling step; and fatty components dissolved in the solvent are recovered from the solvent after the solvent has been separated from the milled rice and bran.

6. A process according to Claim 5, wherein bran is washed from the mixture of milled rice and bran with solvent during the additional extraction step after the milling step.

7. A process according to any preceding claim, wherein the solvent contains water in substantially azeotropic proportions as a constantly boiling mixture.

8. Apparatus for the treatment of brown rice, comprising a mill, means for feeding brown rice into the mill, means to receive mixed bran and rice from the mill, and means for passing a stream of a solvent effective to extract fatty components (including oil) and colouring matter from rice through the mill in contact with rice being milled.

9. Apparatus according to Claim 8, wherein solvent extraction means are arranged to receive mixed bran and rice from the mill and to pass a solvent effective to extract fatty components and colouring matter through the mixture.

10. Apparatus according to Claim 9 comprising an extractor-separator tank arranged to receive rice containing residual bran from the mill; means, in the tank, for agitating rice and solvent; means, in the tank, for separating solvent containing suspended bran from rice; and means for withdrawing solvent containing separated bran from the tank.

11. Apparatus according to any one of Claims 8, 9, or 10, wherein the mill comprises a series of units, each unit including a horizontal, elongate, cylindrical screen having openings therethrough closely spaced from each other substantially throughout its area, said openings being of such size as to pass bran and to retain rice kernels, a cylindrical rotor within and concentric with the screen defining an annular space between the screen and rotor, an inlet for rice grains into said annular space adjacent one end of the screen, an outlet for

rice grains from said annular space adjacent an opposite end of the screen, and helical flights on the rotor constructed to direct rice grains against said screen and to advance the grains toward the outlet; means, cooperative with each preceding and succeeding unit in the series, for conveying rice grain from the outlet of the preceding unit to the inlet of the succeeding unit; and means, operatively connected to drive the rotors, said drive means and helical flights in a succeeding unit being cooperative to exert back pressure on rice grain in a preceding unit.

12. Apparatus according to any one of Claims 8, 9, or 10, wherein the mill comprises a casing; a stationary frusto-conical screen mounted vertically within the casing and spaced laterally therefrom; a frusto-conical rotor within and concentric with the screen having a surface substantially parallel to the screen defining an annular space between the rotor and screen; an inlet for brown rice into said annular space adjacent the upper end of the screen; an outlet for milled rice from said space adjacent the lower end of the screen; and spiral ribs on the rotor arranged to oppose downward flow of rice grains through the annular space and to direct such rice grains outward against said screen.

13. Apparatus according to any of Claims 8 to 12, further comprising a mixer arranged to mix a liquid bran-softening agent with the rice prior to introduction of the brown rice into the mill.

14. Apparatus substantially as hereinbefore described with reference to and as shown in Figures 1 and 2, Figures 3 and 4, Figure 5; or Figure 6 of the accompanying drawings.

15. A process for the treatment of brown rice substantially as hereinbefore described with reference to the accompanying drawings.

16. Rice freed from bran, resulting from a process for the treatment of brown rice according to any one of Claims 1 to 7 or 15.

17. Rice freed from bran, resulting from the treatment of brown rice in apparatus according to any one of Claims 8 to 14.

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