Soybean Preparation

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ABSTRACT AND SUMMARY

Techniques and equipment for a typical soybean preparation plant prior to solvent oil extraction are described. The bean flow is described from incoming beans, to the inlet, to the extractor.

INTRODUCTION

Basically, few equipment innovations have taken place in the preparation end of soybean processing since the original solvent extraction plant started. But, there have been numerous equipment changes in the extraction end. The most striking change in the preparation equipment has been towards larger machines that could process two to three times the volumes processed on the older machines.

Even though most emphasis has been placed on extraction equipment improvement, proper flake preparation is still the more important step. Properly designed and monitored preparation equipment will determine many of the important efficiencies in the entire extraction operation (Figs. 1 and 2).

RECEIVING AND CLEANING

Incoming beans are graded for foreign material and moisture. If storage permits, the beans may be segregated by moisture ranges. This simplifies bean dryer control and reduces moisture variation during processing. If moisture segregation is not possible, the beans should be mixed as much as possible both before and after drying.

Normally, the beans will be cleaned prior to drying. Cleaning will remove large trash, dirt, sand, and loose hulls.

Cleaning is important to reduce the danger of fires in the soybean dryer and to help ensure a constant flow through the processing equipment. Additionally, foreign matter is high in fiber content and must be removed in order to produce low fiber meal. A magnet should be incorporated in this area to remove tramp iron.

Basically, the cleaner consists of a sizing operation to remove the large trash and dirt from the beans. The scalping of the large trash can be done either on a reel or on the top deck of a two deck rotating screen. The lower deck on the rotating screen can be used to screen the dirt from the beans.

Loose hulls are removed by pulling air across a thin stream of beans. This hull and dirt removal can be done either internally in a reel type cleaner or in a cascade type aspirator after the rotating screen.

The size of the cleaner will depend on the drying rate. Bean cleaning may also be done after drying to remove loose hulls freed during drying.

GRAIN DRYING

Incoming beans range in moisture from 10-20%. For proper bean cracking and dehulling, a moistuue of 10-11% is required. Drying also loosens the meat-to-hull adhesion and allows easier removal of the hull from the meat.

Soybean dryers consist of a column through which heated air is passed for drying and ambient air is passed for cooling. The amount of drying is determined by the length of time the beans remain in the dryer.

The size of the grain dryer required depends on the method of obtaining incoming beans and the amount of on-site storage. Beans received in excess of 14% moisture must be dried prior to long-term storage to prevent mold and overheating.

One new development in grain and soybean drying has been the recycling of a portion of the air used for cooling the beans back to the fan prior to heating. This preheating of the drying air can save 25% of the fuel usage as compared to a conventional dryer exhausting all the drying and cooling air.

The dried beans are then put into storage for ca. 10 to 30 days. This holding time is called "conditioning time." During the "conditioning time," the beans should be turned occasionally to provide additional blending of moisture variations.

The "conditioning time" allows bean moisture variations to equalize. Large moisture variations will cause operational variations in bean cracking, dehulling, and flasking. Uniform bean moisture levels are necessary for a steadily running plant. Typically, the bean moisture entering the process will be monitored so that the process can be adjusted to fit the variations in bean moisture.

BEAN CRACKING

The beans are pulled from the process bins to the production scale. The production scale is normally a batch type scale and regulates the processing rate of the plant. The scale operation represents a very important responsibility in the plant operation; maintaining the actual production rate within narrow limits of the production rate goal. Large rate variations propagate unsteady operations in both the preparation area and the extraction area.

From the production scale, the beans are distributed to the cracking roll stands.

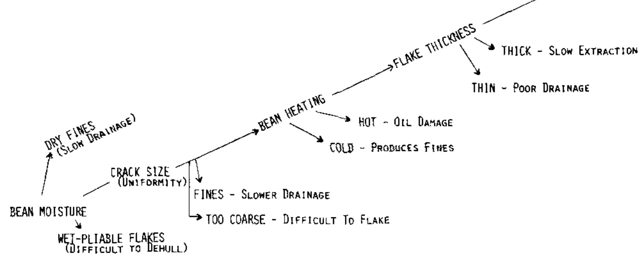

FIG. 1. The ladder to optimum extraction.

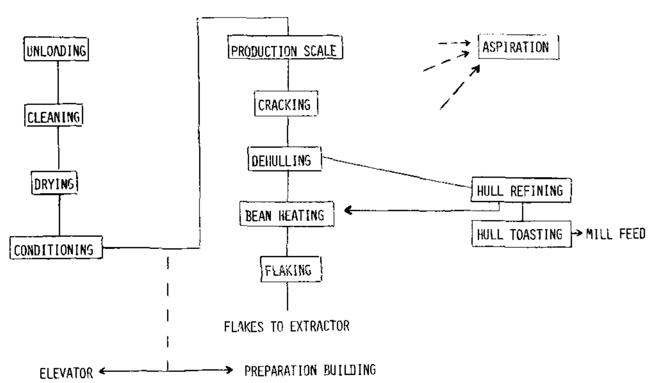

FIG. 2. Soybean preparation.

Cracking roll stands consist of two or three pairs of sawtooth cut rolls, 10 to 12 in. in diameter and 42 to 52 in. long. The corregations on the rolls vary from seven to ten cuts per inch and may have more cuts per inch in the lower rolls. One roll of the pair is stationary while the other roll is adjustable. The tension adjustment of the roll is by a screw arragnement.

Processors have tended to install the larger diameter and length rolls, due to the higher capacity requirements of the newer plants. Another improvement on the newer stands is vibrating feeders which have replaced the older roll type feeders.

The cracking roll operation represents the second major variable which the preparation operator must control. The degree of bean cracking can be from 50% halves and the remainder quarters, to all eighths.

A coarse cracked bean will increase the power consumption of the flaking rolls and produce a larger flake. A fine cracked bean will decrease the power consumption on the flaking rolls and produce a smaller flake with more dust.

The most desirable size of the cracked beans required for optimum extraction largely depends on the type of extractor. The operator must maintain a consistent cracked bean size to ensure consistent operations for dehulling, flaking, and extracting.

FRONT AND DEHULLING

In the dehulling step, loose hulls are removed from the cracked beans so that an extracted meal is produced with a fiber percentage that will be below the present fiber guarantee of 3.3%.

To meet the fiber guarantee on meal, it is necessary to remove over 90% of the true hull material from the bean stream. Similarly, the removed hulls must be essentially free of bean meats since the hull stream is not extracted and any bean meats remaining in this stream represent a serious economic loss. The amount of residual meat in the hulls is measured by a conventional fat analysis. Pure hand picked hulls will contain from 0.5 to 1.0% of fat type material; with good plant operation, the hull stream will analyze from 1.0 to 1.5% fat indicating a very low content of bean meats.

A general dehulling system uses a two-deck rotating screen to separate the cracked beans and hulls into three streams. The top screen separates the larger hulls and meats from the smaller hulls and meats which remain on the bottom deck. The thrus from the bottom deck go into the dehulled bean stream.

The hulls, being lighter than the bean meats, float to the top of the bed of the two screen decks with air hoods. The degree of dehulling is controlled by adjusting the air flow thru the hood, and controlling the distance between the top of the bed of beans and the suction end of the hood.

Cascade aspirators can be used in conjunction with or in place of the hoods. The cracked beans and hulls are thinly spread as they fall thru the aspirator and the hulls are pulled off with air. Aspirators and/or hoods would be used on the flow of beans from both the upper and lower deck on the rotating screen.

In order to produce hull-free cracked beans, a portion of cracked beans are aspirated with the loose hulls. The excess bean meats must then be separated from the hulls in a hull refining system.

The aspiration air is cycloned from the hulls and bean meats which were removed during dehulling. The air exhausts thru a cloth collector to the atmosphere and the bean meats fall to a rotating screen. The screen sizes the hulls and bean meats into three fractions. The finest fraction (essentially bean meats) is returned to the bean stream.

Typically, the middle fraction containing the smaller hulls is refined further either in a gravity type separator or in a cascade aspirator. The separated hulls go to hull grinding. The separated bean meats go either to the cracking rolls or to bean heating.

The remaining fraction containing the largest hulls can be sent either directly to hull grinding or further refined in a cascade aspirator.

The separated hulls are ground in an impact type hammer mill. The ground hulls are typically removed from the hammer mill by air conveying.

The ground hulls are then toasted to "kill" the urease enzyme. The toasting is done in either a vertical pan type toaster or a horizontal tube toaster. The hulls are then put into storage to be mixed with 49% protein meal to produce 44% protein meal or used as a separate feed ingredient.

BEAN HEATING

The dehulled bean particles are next heated to impart increased pliability before flaking. The beans are normally heated to 140-150 F. The higher bean temperature will decrease the power requirements on the flaking rolls but will increase the steam usage on the bean heater. Excessive heat can also damage the quality of the oil.

Beans are generally heated in vertical, stacked, bed-type heaters or rotary steam tube dryers.

Stacked heaters consist of a series of five to eight steam heated pans. Each pan is agitated by sweeps attached to a central vertical shaft. This stirring action moves the beans down thru the unit as they are heated.

The rotary steam tube dryer consists of a horizontal rotating drum containing steam heated tubes. Steam enters thru a rotary seal into a rotating header on the lower end of the dryer. Condensate is dipped from the steam header and leaves thru the rotary joint. The exit temperature of the beans is controlled by adjusting the steam pressure on the tubes.

Rotary steam tube dryers have approximately one half the power requirements of kettle type units and single units can attain higher capacities than single kettle type units.

FLAKING ROLLS

The hot, cracked beans are next sent to a bank of flaking rolls stands. The falking rolls consist of a pair of smooth rolls running against each other. One roll is fixed and the other is movable for applying varying pressures on the bean pieces falling between the rolls. The pressure on the movable roll and the bean flow determines the flake thickness.

The rolls are typically 20 to 24 in. in diameter and are 40 to 50 in. long.

The rolls are turned at 200 to 300 rpm, and there is generally a 10 to 15% speed differential between the two rolls.

A modern flaking stand may consist of two pairs of rolls with each pair being powered with up to a 150 HP motor.

Such a stand would be capable of flaking ca. 300 tons of beans per day. The flaking capacity of the flaking roll will depend on the size of the cracked bean particles, the temperature and moisture of the bean particles, and the flake thickness desired.

The larger capacity flaking machines represent one of the newer advances in milling equipment. The large capacity flaking machines have allowed crush capacity increases with only minor increases in space requirements.

The new machines have improved hydraulic pressure devices for maintaining constant pressure on the adjustable roll and vibrating feeders. Vibrating feeders do not have the plugging problems experienced with the roll feeders and consequently result in a more even bean feed to the flaking rolls.

The use of V-belts to maintain roll differential instead of gears or roller chain is another recent development. V-belt differential drives are quieter, longer wearing, and result in more event flaking roll wear than the previous systems.

The flaking rolls represent one of the most important operations in the processing plant. The proper flake thickness has a large bearing not only on the oil extracting efficiency, but also on the desolventizing efficiency.

The optimum flake thickness for any given plant situation is that thickness which gives the lowest residual oil level in the flakes leaving the extractor. This optimum thickness is the result of a number of counterbalancing relationships such as the following. (a) Thinner flakes increases the rate of extraction because the diffusion distance for the solvent is reduced. (b) However, thinner flakes reduce flake bed percolation rates and thus limit the ability of the solvent to get through the flake bed. This phenomena is the result of two factiors: first, thinner flakes are more pliable, tending to deform in the flake bed and seal off the flow passages; and second, thinner flakes generally contain more dust which will seal off the flow passages in the bed.

While the actual flake thickness is determined at the flaking roll, milling variables ahead of the rolls largely determine what the ultimate optimum flake thickness for any given extractor should be. The most significant of these variables are bean moisture, elevator conditioning, size and size distribution of the cracked beans and cracked bean temperature. These variables are adjusted to give the thinnest flake which still gives satisfactory percolation rates for the extractor being used.

The flake thickness is affected by several processing variables and, consequently, the flaking operation requires frequent checking by the preparation operator. The proper operation of each flaking roll should be checked by the operator a minimum of twice per shift.

The falking rolls represent not only a high energy consumption cost, but also a high maintenance cost area.

Typically, the ends of the rolls are blocked to prevent cracked bean leakage past the rolls. This blocked area does not flake beans and consequently does not wear. Eventually, these ends of the rolls will run together and break out if not ground off. These high ends must be either ground off by hand while the rolls are in the stand or the rolls must be removed and the high ends removed in a lathe.

This grinding, plus the proper setting of the end blocks, represents both a large problem and cost with flaking rolls.

Aspiration is an important auxilliary operation in the preparation area. It is used to control "dusting-out" from equipment openings and to eliminate moisutre condensation on equipment surfaces. Additionally, aspiration of the flaking rolls, usually by means of suction points on the conveyor receiving flakes from the rolls, is desirable to remove surface moisture from the flakes.

The flakes leaving the flaking rolls are conveyed from the preparation area to the extractors in the extraction area.

RESULTS AND DISCUSSION

It would be difficult to over-emphasize the importance of bean preparation to smooth efficient operation of the extraction plant. The preparation operator determines the actual production rate of the plant. Every surge which he causes in flake rate to the extractor (or permits to occur because of a change in the bean quality) must be handled and compensated for by each of the subsequent processing steps. To illustrate this point, consider a few of the problems which can result from a large flow variation from the preparation process:

1. The plant "runs out" of solvent because of excessive hold-up in the extractor.
2. The Desolventizer Toaster (DT) becomes overloaded and excessive flakes are carried over with the vapors.
3. Meal leaving the DT contains hexane due to poor level control in the DT.
4. The oil distillation system becomes overloaded and produces low flash point oil and pressure fluctuations in the vent system.
5. Meal moisture gets out of control.
6. The meal grinding system is overloaded directly by the surge flow or by higher moisture meal.
7. Residual oil in flakes is high and varies widely from shift to shift.

In addition to his part in making it possible for the rest of the plant to operate smoothly, the preparation operator largely determines extraction efficiency by the kind of flakes he sends to the extractor and meal quality as measured by fiber analysis by proper control of his cracking and dehulling operations.

There is an old adage saying in effect that proper preparation is the key to success. The soybean preparation process has to be a prime example of the correctness of this saying.

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