close (Fig. 2).

Nutritionally, flours obtained by the germination process with very low TI values are of high quality (15).

Lipoxygenase Activity

Soaked and germinated soybeans showed a decrease in lipoxygenase activity as this enzyme is thermolabile and some heat is generated during germination. Steam destroys lipoxygenase rapidly (Fig. 3).

Full-fat soy flour has no lipoxygenase activity and thus high stability, as shown by shelf-life testing.

Milling Capacity

During germination, there is a mobilization and partial hydrolysis of carbohydrates; oil also migrates. So, as germination time is extended, oil migration makes the milling difficult. A 43% decrease in milling capacity was observed at 72 hr germination time (Fig. 4). This is a disadvantage that could be overcome by using a pin-type mill.

Flavor Score

As lipoxygenase activity decreased, flavor scores improved. The increase in flavor scores is higher with steaming and drying of soybeans, which eliminate the bitter flavor.

Odor Score

There is a relationship between odor and flavor scores (Table I). Germination helps improve the odor scores if steaming and drying follows. Soybean germination modifying effects are important to the quality of the full-fat soy flour because as flavor and odor scores increase, stability is improved, nutritional improvement because of the low TI is observed and the reduction of oligosaccharides means much less flatulence.

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The Art of Soybean Meal and Hull Grinding

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ABSTRACT

Grinding soybean meal and hulls may be considered an art—rather than a pure science—because of the need to blend properly all of the parameters involved to produce the desired finished product. Grinding soymeal for a protein supplement to animal feed is best achieved by using a side-fed mill, with plenty of air throughput and a large screen area. However, for the fine grinding of soymeal or isolate products (50-mesh or finer), an impact turbo mill with closely controlled clearances is generally used. Soybean hull grinding requires a mill with a high hammer-tip speed, wear-resistant grinding elements, good air flow, and again, large screen area. The size and speed (rpm) of each mill in a system is usually a function of the location of the mill in the system, and the type of system selected to deliver the desired finished product.

Soybean meal grinding is a very complex endeavor, not only from the point of view of all of the parameters involved in the selection of a pulverizer to perform the reduction—such as air, screen area, tip speed of hammers—but also from the simple placement of the grinder in relation to other pieces of equipment to achieve the desired end-product. Because it requires proper manipulation of all these parameters, we call this endeavor an "art," rather than a simple science.

Changes in the preparation of meal prior to the grinding process have caused some significant changes in the effectiveness of meal grinding. Most people remember what probably was the most significant change, i.e., the change from the expeller cake process to the solvent extraction process. Then, in recent years, the advent of head-end dehulling greatly improved the capacity and quality of meal grinding.

The soybean industry has basically standardized on a finished meal specification, which primarily is "everything through a 10 mesh screen, with 50% maximum through a 24 mesh screen, and 1% maximum through an 80 mesh screen." This grinding specification can be more easily achieved if we have good screening efficiencies on the screen ahead of the grinding process. Too often, many acceptable fines (minus 10-mesh) are carried to the grinder where they are, unfortunately, further reduced simply because the bed depth on the vibrating screen was too great, or other complications arose in the screening process causing the fines to carry over.

Needless to say, dehulled solvent extracted meal is very friable. Therefore, the selection of a grinding process which will not grind this friable meal too fine is important. The

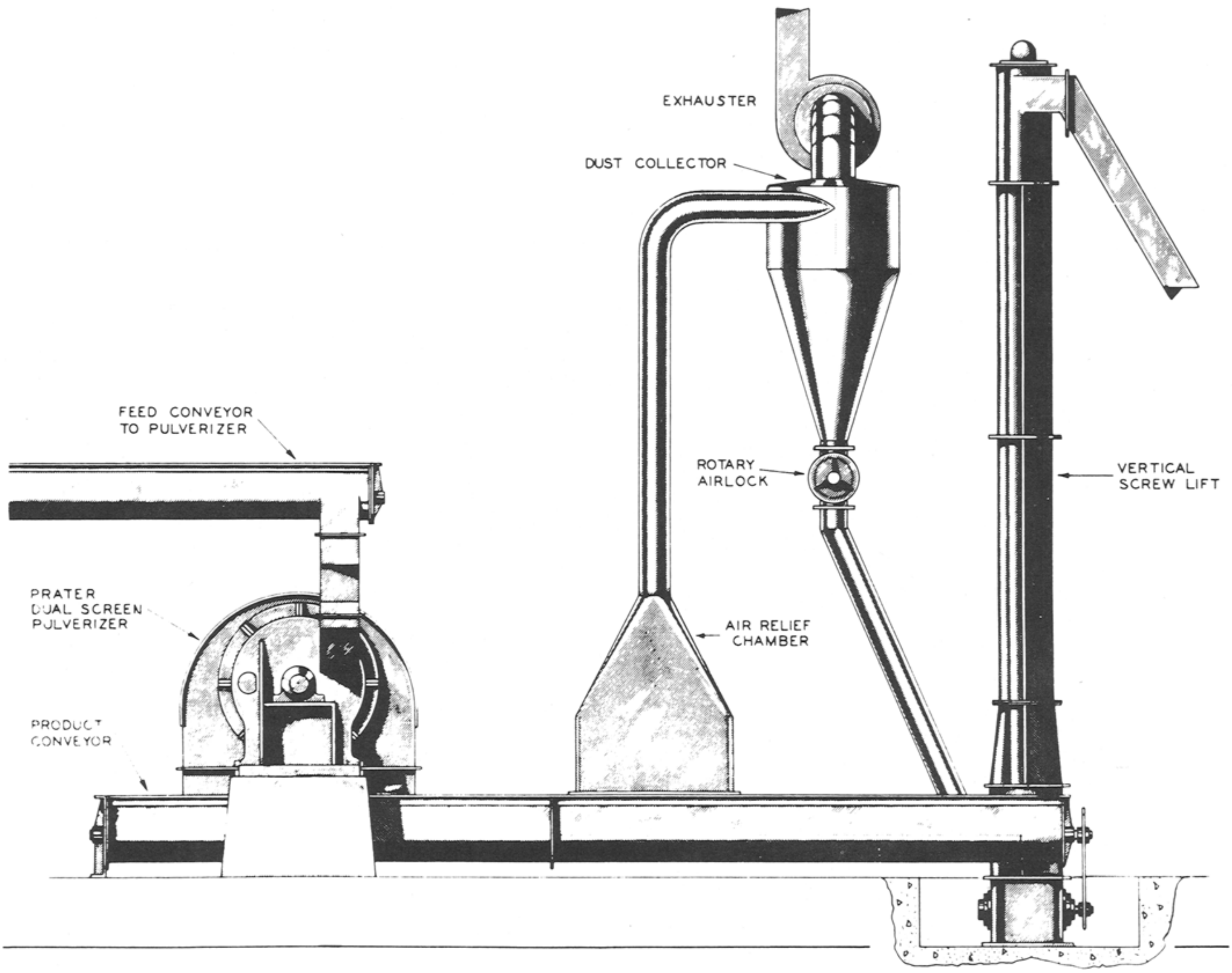

FIG. 1. A typical installation of the Prater Dual Screen Pulverizer.

first important parameter to consider to help this situation is the proper relationship between horsepower and screen area. The nature of grinding a product such as solvent extracted soybean meal is such that using a mill with a large screen area is an asset to reducing objectionable fines. One cannot simply add more horsepower to an existing small screen mill to achieve a good, high volume meal grinder. This is because as the driving force (horsepower applied) is increased while holding to a fixed screen area, the resultant grind will be finer. Obviously, in meal grinding, this is undesirable. Referring for a moment to a mill familiar to most of you since it is the mill used to grind most of the soybean meal processed in the U.S. today, the PRATER DF-11 "Dual Feed Dual Screen" pulverizer has not one but two screens in it, providing a total of 1,710 square in. (1.1 square m) of screen area. This means that with a typical driving force of 100 HP, you end up with a ratio of over 17 square inches of screen area per horsepower applied. The lower this ratio becomes, the greater the amount of objectionable fines in the finished grind.

A second, important consideration to reducing objectionable fines is simply to get the product being ground out of the mill, after it has been reduced to the proper granulation, just as quickly as possible. Of course, a large screen area will help you do this. However, in addition to a large screen area, proper use of the air passing through the mill is a great help in reducing fines. A pulverizer, which mechanically is nothing more than a rotor with free-swinging hammers turning inside a mill case or other enclosure, can be thought of to act as a fan. The air generated by this fan action, particularly in a large diameter mill operating at 1,800 rpm, is very definitely a factor in grinding, and, properly used, is an asset to the efficient grinding of meal.

This air naturally enters at the eye of the mill, entering through both sides under the suction caused by the turning rotor and exits out the bottom at the discharge. If this system were to be choked or starved for air in any way, the capacity and the resultant granulation would be adversely affected. In other words, it is good to let the mill "breathe." If you are discharging into a mechanical conveying system, simply balance the air created by the mill with a small exhaust fan and dust collecting system, sized to accomodate the air generated by the mill. This is normally done by taking suction from the plenum chamber built on top of the conveyor near the mill discharge with the return of the separated particles from the collector to the system further down the conveyor line. In setting up the air relief system in this manner, you should have ca. 2" (50 mm) negative water gauge at the discharge of the mill. In the case of our own DF-11 again, the amount of air suction to balance this mill operating at 1,800 rpm, is ca. 2,100 cfm (60 m^3/min).

The third thing to consider in the mechanics of operating the grinder to control granulation is to use the principle of "gradual reduction," rather than "instant reduction" to help reduce fines. For instance, our meal grinders use the triple reduction process, rather than the instantaneous confrontation of the meal on the hammer section of the mill. By feeding the meal from the side of the mill across the three distinct steps in particle reduction in the triple reduction rotor, you also realize the benefit of spreading out the product being ground, so as to put the meal across the total screen area for final reduction in the most effective manner possible. The meal is gently accelerated, avoiding sudden impacts, which occurs when top feeding meal abruptly into the area between the hammers and the screen. This gradual three-step reduction concept has also gained much acceptance in the distilling industry, where, as in the soya industry, the controlled granulation of corn, rye, malt and other distillers grains is very important.

Meal grinding systems in soybean plants usually operate on a 24-hr/day basis with the mill motor loaded to ca. 80% of its full load readings. In so doing, the mill can be permitted to run continuously without fear of surges or overloading. Under these conditions, we feel that a safe, conservative grinding rate on soybean meal, yielding an acceptable finished product grinding usually through a 1/4" (6.35-mm) perforated screen would be 350 lb/HP/hr (159 kg/HP/hr).

The fine grinding of soyameal for the production of edible protein, (or other similar products), requires a grinder of a different type. Once the requirement of fineness is smaller than ca. 90% minus 50 mesh, you have exceeded the limits of what a conventional hammermill can deliver.

For such an application, the additional parameters of very close tolerances, high speed, and shear become a necessity. A fine grind of this type is generally produced in an impact turbo mill or a Prall mill. The fine grind is obtained by feeding the product into the center of a mill having a fixed stator (screen) with intermittent grinding plates with a fixed, bladed turbo which revolves at a high rate of tip speed, coming within very close clearances to the fixed stator. This clearance is usually never more than 2-3 mm. Again, as is the case with a hammermill, good air flow is important. A typical capacity in grinding soyameal to 95% minus 200 mesh in such a machine would be 50-60 lb/HP/hr (22.7-27.2 kg/HP/hr).

Grinding of hulls poses quite a different problem. Hulls, being very light and fibrous, require a high impact speed, good air flow through the mill, large screen area in the mill, and high wear-resistant grinding elements in the mill. A conventional hammermill having all of the above generally is operated at 3,600 rpm using a 1/8" (3-mm) screen to accomplish good hull grinding.

However, most people agree that it is more desirable to grind at 1,800 rpm instead of 3,600 rpm whenever possible. Thus, if we consider the triple reduction large diameter DF-11 Mill previously mentioned in this report, having a screen area of 1,710 square in. (1.1 square m), plus a hammer tip speed of 18,600 ft/min (212/mph or 340 km/hr), this is sufficient to accomplish a good grind on hulls through a 1/8" (3-mm) screen. Our records show a conservative grinding rate, under these conditions: toasted hulls = 100 lb/HP/hr (45.4 kg/HP/hr); untoasted (green) hulls = 50 lb/HP/hr (22.7 kg/HP/hr).

Let us take a brief look at meal grinding systems. The meal grinding stage in a meal production prep-room usually comes after the extractor, the desolventizer-toaster, the dryer (if possible), and the meal cooler (if possible). If the dryer is not used or is placed after the grinder, the condition is referred to as "wet meal grinding." If the meal is ground on-stream without benefit of a cooler, the process is known as "hot meal grinding." Meal from the desolventizer-toaster generally has ca. 18-20% moisture, and it is desirable to reduce this level before grinding, if possible.

In the early days of soybean solvent extraction operations, the most common milling set-up was the "two-stage" grinding system. In this system, the processed meal from the DT tank is first sifted through a can #12 screen. Some of the meal (as much as 30%) from the DT tank is minus 12-mesh (1.7-mm) and will pass through the screen into the system without going to the mill. The overs from the first sifter are then ground in as many mills as necessary to keep up with plant production requirements.

If the product is quite friable and without hulls, it is sometimes desirable to operate these first mills at 1,200 rpm to reduce the impacting force, and in so doing, reduce the potential of making fines. The material then passes from these first stage mills to a second sifter with the material passing through the sifter going into the finished meal conveying system. The overs from this second sifter, which in the early days before head-end dehulling consisted of primarily hulls, were then passed through a second stage mill, which is the same type of mill—only this time it must of necessity be an 1,800 rpm mill to insure that all of the material will be reduced to proper size.

The most common system of meal grinding today is known as the single stage grinding system. The advent of front-end dehulling equipment makes this system even more popular. In the single-stage system, the incoming meal is first passed over a sifter, with the material that is already down to size passing through the sifter and into the conveying stream. The overs from the sifter then are passed to as many mills as necessary to keep up with plant production requirements. After grinding, the finished material is returned to the original sifter again. The overs are passed through the mils once again. Usually, the amount of overs returned to the mills for grinding a second time rarely exceeds 10%. These mills usually are 1,800 rpm pulverizers in this system.

Most of the pulverizers supplied to the industry today are either replacements or additions to existing systems, rather than for newly constructed plants or facilities. As such, one is more apt to find modifications and additions to either the single-or two-stage grinding systems, rather than the simple flow patterns suggested here. However, when new facilities are planned today, they are apt to include the extractor, desolventizer-toaster, dryer and cooler, and then the single-stage, on-stream grinding set up, as outlined; however whatever system is used in finality, we can all be sure that the world's demand for protein, which is great now and can only increase in years ahead, just makes it that much more important to all of us to plan and utilize our facilities as efficiently as we can.