Head- and Tail-End Dehulling of Soybeans

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ABSTRACT

Head-end and tail-end dehulling systems are compared, including yield, investment costs, and energy consumption. A comparison of the European and US methods of using head-end and tail-end dehulling is provided. A combination of front-end and tail-end dehulling systems is shown, including the results in yield. Power consumption and investment costs are presented in comparison to front-end dehulling.

INTRODUCTION

The main object of dehulling soybeans is production of high protein meal. In the United States, more than 50% of the crushed soybeans are processed to high protein meal, whereas in Europe the percentage of this quality is well below 50%. The reason for this situation lies in different market conditions. Although the quality standards applied on either side of the ocean are the same, it appears that the American buyers of soybean extraction meal are more quality-concerned than are Europeans.

Furthermore, soybeans are not uniform in regard to oil, protein, crude, fiber and moisture content. Their properties change not only from year to year, from country to country, but also from place to place in the same country depending on soil and weather conditions. Besides these properties, the degree of maturity, the content of damaged beans and possible deterioration during storage, play an important part with regard to the front-end dehulling.

In the United States, oil millers buy a substantial part of their soybeans during harvest season. The moisture level ranges from 16 to 18% and the beans need to be dried to ca. 13% for safe storage. After storage, in a second drying step, the beans are dried for dehulling to 10-9.5%, depending upon the process requirements.

In recent years, farmers and farmer cooperations have built their own drying and storage facilities and deliver the soybeans with ca. 13% moisture to the oil mills. This development will in the future increasingly reduce the need for large seed storage including the drying installation for storage purposes at the oil mills.

Imported soybeans mainly from the United States and South America are processed in Europe. The contract conditions call in general for grade US yellow II with maximum 14% moisture at the port of loading. Once the beans are delivered to the oil mill, the moisture ranges from 12% to a maximum of 13%. During transport, unloading and reloading in harbors, a gentle drying of the seed of ca. 1% takes place.

All the above described circumstances take in one or another way an influence with regard to the conditions of soybean front-end dehulling. When we compare American and European systems, we must keep in mind that the starting conditions are not identical and also that the quality standards of the final meal varies to a certain extent. All these factors have influenced the development of the dehulling, resulting in a variety of solutions to this process. However, some basic principles are common to all of them.

COMPARISON OF HEAD-END DEHULLING

In general, the principal processing steps in the United States and Europe are the same, namely precleaning, drying, tempering, cleaning, crushing and hull separation. A closer look at the individual processing steps will reveal the differences.

Drying-Tempering

In the United States, the soybeans are dried to about 10% or a little less and the recommended tempering time is preferably 5 days or more, whereas in Europe the moisture level of the beans is normally adjusted such that a tempering time of one day is sufficient. For this reason, the seed dryers are designed to dry the beans to a 9% moisture.

Hull Separation

After the crushing rolls, the granulation of cracked beans and hulls to be processed in the hull separation can be considered to be similar in American and Europe. Although the mode of hull separation in both cases is about the same (namely, grading of cracked beans and hulls with subsequently individual removal of the hulls by air aspirators), there are two different principles behind it.

In the United States, the aspirators are set to remove not only the hulls, accounting for about 6-8% of the bean quantity, but additionally also 3-5% of the cracked beans, giving a total lifting of 9-13% to assure good separation of hulls from the main stream. The liftings are conveyed to a secondary dehulling to recover the aspirated bean particles by hull sifters or gravity tables.

In Europe, the hull sifters and aspirators are set as close as possible to the optimal operating conditions, allowing the hull removal without secondary dehulling. This is possible because of the different design of the machines.

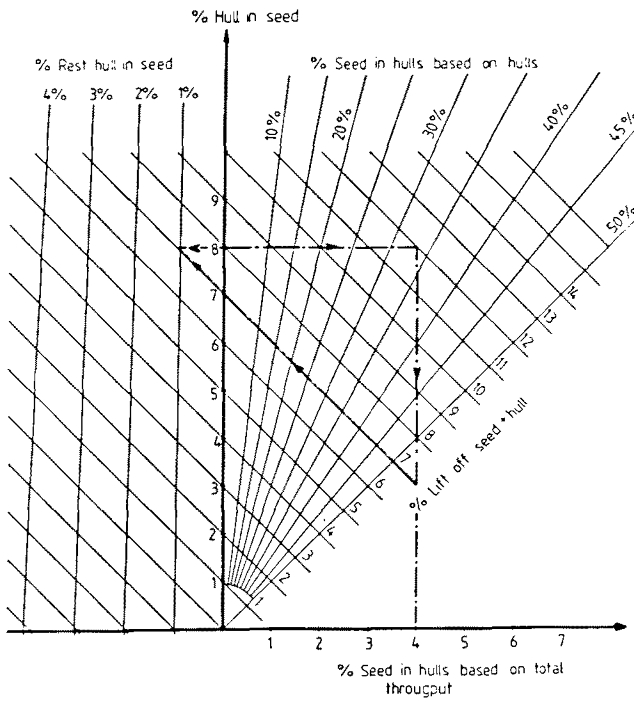

FIG. 1. Graphic to determine the rest hull content in dehulled beans. Example: Soybeans with 8% hull content. Total lift off 12% (8% hulls + 4% seed). Return from 2nd-stage dehulling: 4% seed + 1% hulls = total 5%. Actual lift off: 12%-5% = 7%. Result: Rest hull content in dehulled seed 1.1%.

TAIL-END DEHULLING

In contrast to the front-end dehulling, the starting conditions in the tail-end dehulling are about the same. For this reason, the principal system applied does not differ very much, although a variety of detail solutions can be found, caused by individual experience or design of plant layout, in case the tail-end dehulling has been added to an existing plant. In all cases, the tail-end system follows the following principle: sifting of extraction meal; grinding of over; and separation in low protein (LP) and high protein (HP) fractions.

Because of different market demands, more attention to the granulation of the extracted meal must be given in the United States. This condition applies to all oil mills whether or not they are equipped with tail-end dehulling. In general, the meal-finishing section in the United States is more extensive than in Europe.

Based on this condition, the extent of the meal-finishing section with tail-end dehulling compares as given in Table I.

TABLE I

Tail-End Dehulling: Process Comparison between USA and Europe

USA	Europe
1st stage sifting grinding of overs	Sifting
2nd-stage sifting grinding of overs	Grinding of overs
Separation in LP and HP meal by gravity tables or aspirators	Separation in LP and HP meal by sizing and aspirators

Meal Grinding

In the USA, hammer mills operate with 92 m/sec beater speed and sieve openings of 6-8 mm are used. In Europe, the extracted meal is marketable with a coarser granulation. This allows for operating the hammer mills with 55-65 m/sec beater speed and sieve openings of 3.5-4.5 mm. This way of operation is more a disintegration of the lumps than actual griding thus producing less fines. In most cases, no control sifting after griding is installed in Europe.

Separation into LP and HP Fractions

To separate the ground fraction, gravity tables or dual-aspirators are used in America. In Europe, the ground extracted meal is sized into three fractions. The fine fraction is led directly to the LP stream, whereas the two other fractions are individually aspirated on the sizing machine as well as in subsequent aspirators.

COMBINATION OF HEAD-END AND TAIL-END DEHULLING

Depending on protein and fiber content of the soybeans processed with tail-end dehulling, up to 25% of the plant production will be 49% protein meal, and 75% of the plant production results in 44% meal. In praxis, the fraction of 49% protein meal is increased to 35 or even up to 40% by removing the hulls and other trash in the cleaning section.

A method to increase the yield of 49% meal further is to use partial head-end dehulling. This process eliminates the seed dryer after storage and the tempering bins. Although the seed is not dried to 10% moisture content and has not undergone the tempering process, a substantial part of the hulls becomes loose during the cracking. Hull separators installed after the cracking rolls remove the loose hulls as used in the traditional head-end dehulling.

Depending on bean properties, it is estimated that up to 70% of 49% meal of the plant production can be obtained. The advantage of this system is evident since the bean dryer and tempering bins are no longer needed and consequently less steam is consumed.

Considering a standard oil mill designed to process soybeans to 44% meal only, the following additional equipment is required for the head-end dehulling: seed dryer, tempering bins, hull separator, and hull griding or toasting. The additional energy consumption per ton 49% meal produced is as given in Table II.

TABLE II

Power Consumption (per 1 ton 49% meal produced)

Process	Electric energy kWh/ton	Steam consumption kg/ton
Seed drying (13-9%)	6.7	200
Hull separation	2.5	–
Hull grinding	2.2	–
Total	11.4	200
	116.6 ←	┘
	128.0	

Provided that a standard oil mill is equipped with meal sifters and hammer mills, only the machines for the seaparation into 44% and 49% meal are required. The additional energy requirements per ton 49% meal produced based on a yield of 30% is: 10.5 kWh/ton. If we take the specific investment (investment based on one ton meal produced) necessary for the production of 49% meal covering the above head-end dehulling as 100%, than the specific investment of the tail-end dehulling based on 30% yield will be up to 90%.

The additional investment for the head-end vs tail-end dehulling taken into account for the above cost evaluation covers the mechanical equipment only and does not take into consideration the costs for tempering bins and other building sections. If we consider the additional costs for tempering bins and differences in power consumption, the advantage of the tail-end dehulling becomes more evident.

The combined installation features partial head-end dehulling without bean dryer and tempering bins; however, tail-end dehulling based on 60% yield of 49% meal shows the energy consumption given in Table III.

Under the above conditions, the specific investment covering the combined installation, based on 60% yield HP meal, amounts to 75% compared to the traditional head-end dehulling.

TABLE III

Power Consumption of Combined Head- and Tail-End Dehulling (per 1 ton 49% meal produced) Based on 60% yield HP Meal

Process	Electric energy kWh/ton
Head-end hull separation	4.2
Hull grinding	1.8
Tail-end dehulling	5.3
Total	11.3

FUTURE

As these discussion have shown, the combination of head- and tail-end dehulling presents a possible way to save costs and energy. However, development has further progressed to a new system combining fluidbed technology with front-end dehulling without the need of a common seed dryer and tempering bins. The merit of this process is a special heat-treatment of the soybeans and the following crushing, dehulling as well as the flaking, being made with hot beans. Since this system is developed in connection with the head-end dehulling, it is called "hot dehulling," for which several patents exist. The principal difference between conventional and the hot dehulling is shown in Figure 2.

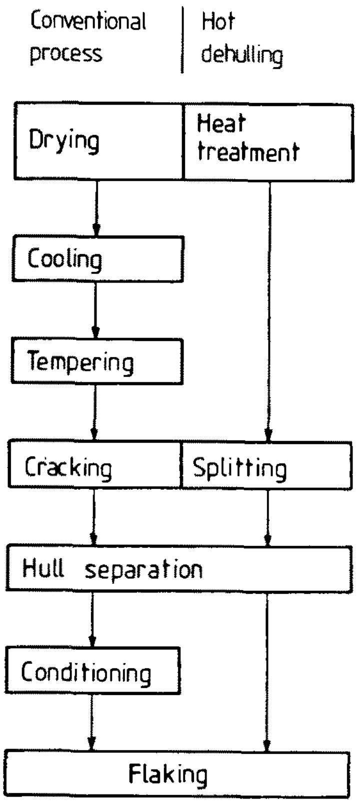

FIG. 2. Comparison of conventional and hot dehulling of soybeans.

It can be noted, with the hot dehulling system, that energy for cooling of the beans in the seed dryer as well as the energy for the conditioning of the cracked beans can be saved. But how does this system work in practice?

The heat treatment of soybeans is made in a fluidbed. Hot air, at higher temperature levels than used in conventional seed dryers heats up the beans in a short time in order to free the hulls. The hot beans are then processed, preferably in splitting machines working on the impact principle. By the impact the whole beans are split into half-beans. At the same time the hull, enclosing the whole bean, is fractured and separated from the bean particles. The splitting machine produces far less fines than the cracking with fluted rolls.

For this reason, the removal of coarse hulls from the half-beans can be made with high capacity aspirators. This aspirator type also separates at the same time the smaller particles from the hull-free half-bean fraction. The said small size fraction is additionally handled by the fine hull separation equipment.

The dehulled beans can be flaked directly on 800 mm diameter rolls or, if required, be further reduced in size, by craking rolls, equipped with one pair of fluted rolls, for flaking with smaller roll diameter. Wherever possible, extensive use of air recirculation is applied to reduce energy consumption and to reduce to a great extent the exhaust air quantity.

The advantages of the hot dehulling system compared to the conventional system are: less steam consumption; less investment in building and equipment; less fine content in flakes; and lower environmental problems.