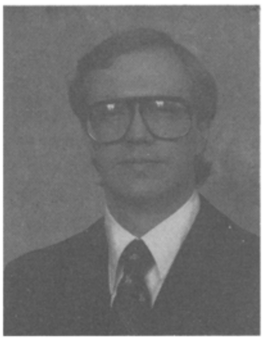

Handling, Transport and Preparation of Soybeans

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ABSTRACT

Present techniques of transportation, receiving, drying, storing and preparing of soybeans are discussed and compared with future techniques.

INTRODUCTION

Transportation, handling and preparation of soybeans affect the quality of finished products such as neutral oil yield, crude oil quality and fiber content and protein quality of soybean meal. Separation of foreign matter and moisture control during storage are two critical factors affecting subsequent processing.

SHORT-TERM FARM STORAGE

Following harvest, soybeans are first handled at small farm storage facilities. They may be safely stored for 6 months in weather-tight storage bins at the farm if the maximal moisture of the soybeans is 13% at the time of storage. Soybeans containing 12% moisture have been stored for as long as 3 years without causing germination or an increase of the fat acidity value. Soybeans stored in weather-tight bins will have a seasonal migration of moisture. Soybeans stored at 12% moisture in September may have moistures as high as 18-20% in February in the outer layer of stored soybeans because of the moisture that moves from the warm core of the bin to the cool outer surfaces of the stored beans and inner bin walls. However, in the spring and summer months, moisture may migrate to the cool core of the stored soybeans from the outer zones of the storage bin. Forced air circulation may be used to control moisture accumulation and migration in stored soybeans not only on the farm, but also at the industrial elevator. Figure 1 indicates that forced draft aspiration of stored soybeans should not be used when the relative humidity of the outside air is 70% or greater. It is important to control the moisture content of stored soybeans at a level no greater than 13%. Soybeans stored with a moisture content greater than 13% may begin germinating. The process of germination generates heat, which may cause heat damage to the protein and oil in the soybeans. Furthermore, heat generated from germination may cause fires in stored beans by spontaneous combustion. Soybeans containing more than 13% moisture which are stored at temperatures in excess of 10 C encourage the growth of fungi, insects and mites. Soybeans themselves, as well as foreign matter such as green leaves, stems, pods and weed seed, contribute to the moisture content of the stored material.

PERCENT MOISTURE IN SOYBEANS	RELATIVE HUMIDITY
6.5%	35%
8.0	50
9.6	60
12.4	70
18.4	85

FIG. 1. Equilibrium values for soybeans at 25 C.

TRANSPORTATION

Soybeans are transported by truck, rail and barge from the point of harvest to receiving stations at industrial elevators such as country elevators, terminal elevators or mill elevators. Transportation should deliver grain unchanged from the farm to the distribution center and, in so doing, minimize the separation of hulls from whole soybeans and formation of "splits."

RECEIVING

At the mill elevator, samples of soybeans are manually analyzed for foreign material, moisture, "splits," heat damage, oil content, protein content and free fatty acid content. Soybeans are graded according to the analyses and transferred to storage. As shown in Figure 2, soybeans may be transferred from receiving to short-term storage if the moisture content is greater than 13%, directly to long-term storage if the moisture content is less than or equal to 13%, or directly to scalping for separating large, foreign material such as cobs, corn stalks and other debris.

DRYING

After scalping, soybeans are dried and cooled for storage. If the soybeans are going to be processed to low protein/high fiber meal, they can be stored at 13% moisture if the stor-

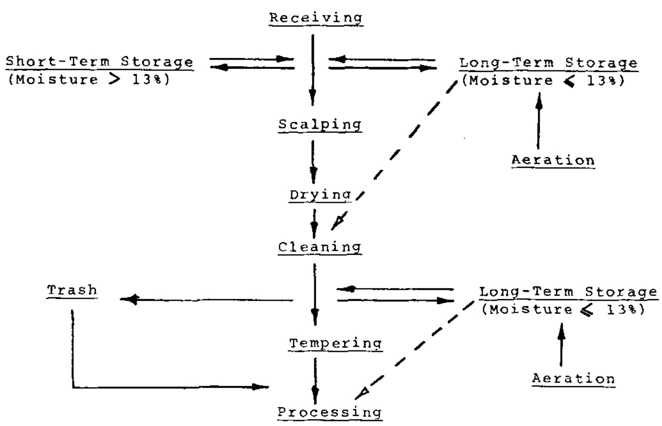

FIG. 2. Typical mill elevator flow.

age tank or silo is aerated. If, however, soybeans are to be processed to high protein/low fiber meal, they must be dried to 10% moisture or less.

The requirements for good soybean drying using countercurrent flow, open-flame dryers are: (a) a uniform unrestricted flow of air; (b) a uniform application of heat from side to side and top to bottom; (c) a uniform movement of grain passing through the drying and cooling section of the dryer.

If soybeans are to be dried from 18 to 13% moisture, the grain must be heated to 49 C. However, if the soybeans are to be dried from 13 to 10%, the soybeans must be heated to 65 C. In no case should the soybeans be heated to a temperature greater than 76 C because discoloration and protein denaturation of the finished products will result.

Fuel savings for a soybean dryer is possible. Boiler flue gas can be mixed with the burner inlet air to reduce the energy costs by increasing the inlet air temperature to the burner. This works most satisfactorily when natural gas is the fuel used in the boiler. If boiler stack gases are used as a supplementary heat source for whole soybean drying, portions of the soybean dryer should be constructed of stainless steel. Exhaust air from the cooler section of the dryer may also be recycled to the burner air inlet to warm incoming air to the burner. Tests have revealed that recycling of cooler-zone exhaust air can yield a fuel savings of 25-50%.

Typically, soybeans are cleaned at 3 times the normal processing rate in the oil mill whereas they are dried at 2 times the normal processing rate in the oil mill. Vibrating or stationary screens may be used to separate weed seed, dust and other fine foreign matter from the dried soybeans. Cleanings, including weed seed and dust are usually separated and then returned to the bean stream for further processing, where the foreign material must again be removed.

STORAGE

Soybeans are stored at the mill elevator in either concrete silos or steel tanks. Concrete silos are quite expensive and include the cost of material handling equipment to fill and empty them. Steel tanks have been used recently in the United States for storing large quantities of soybeans. A typical steel tank is weather-tight and has a 27-degree conical-shaped top which matches the angle of repose of whole soybeans. If a temperature increase is sensed in a storage tank of soybeans, it is necessary to move the soybeans out of the tank until the cause of the temperature increase is corrected. Figure 3 shows how heavy, foreign material tends to form a central cone or core in the stored bean pile and how the light, foreign material such as green leaves, stems and pods, tends to migrate to the wall of the tank. "Hot spots" will usually occur in the heavy foreign material core and can be removed by drawing soybeans from the middle of the storage tank. Hot soybeans may either be cleaned and restored, dried, if necessary, or sent directly to processing.

Moisture control is essential in long-term storage of soybeans. An aeration rate of 0.1 cu ft/min of air/bushel of storage capacity is typical design practice. It is necessary to monitor the temperature of stored soybeans continuously. Some modern processing plants use thermocouples located inside a rigid conduit which is placed into the stored soybeans. It is good design to have a temperature-sensing probe for every 50-100 cu ft of soybean storage capacity. If continuous temperature monitoring is used, "hot spots" in stored soybeans can be detected early and measures can be taken to correct the problem. Audiovisual alarms may be connected to the temperature monitoring system to alert the elevator operator.

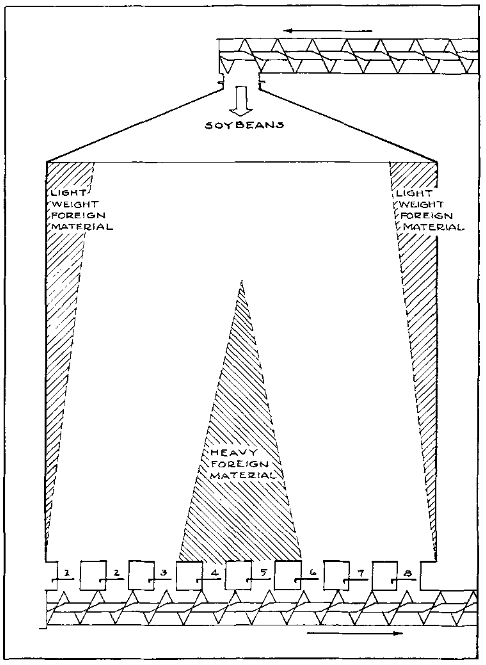

FIG. 3.

Short-term storage often is used to temper soybeans between drying or long-term storage and/or processing. A tempering time of 7-10 days is considered adequate by most processors. During tempering, temperatures should not exceed 24 C and the moisture content of the soybeans should be 10-12%. The purpose for tempering soybeans is to allow hulls to shrink away from the soybean while allowing soybean moisture to reach equilibrium. Tempering of soybeans provides more uniform operation in the oil mill, which includes efficient hull removal.

PREPARATION

Preparing soybeans for production of low protein/high fiber meal begins with a secondary cleaning of whole soybeans as they enter the preparation building. The cleaning removes any light hulls that have worked loose in storage or transport and any foreign matter which had been separated previously and returned to the whole bean stream between storage and processing. Soybeans are then continuously weighed to provide a guide for production control of the processing plant. Figure 4 shows a typical material flow through preparation.

Cracking soybeans into eighths will yield the following screen profile: on 6-mesh, 10-15%; on 10-mesh, 60-70%; on 20-mesh, 5-15%; through 20-mesh 0-3%.

Soybeans are conditioned to 71-76 C at 10-12% mois-

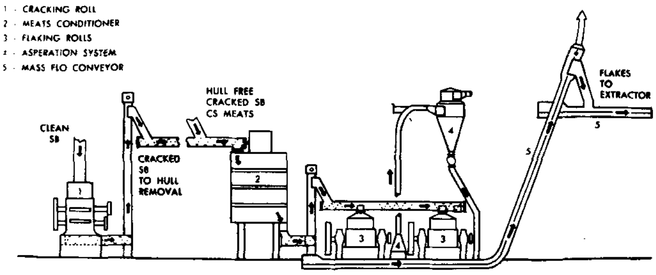

FIG. 4. Flow chart of soybean (SB) and cottonseed (CS) meats preparation for direct extraction.

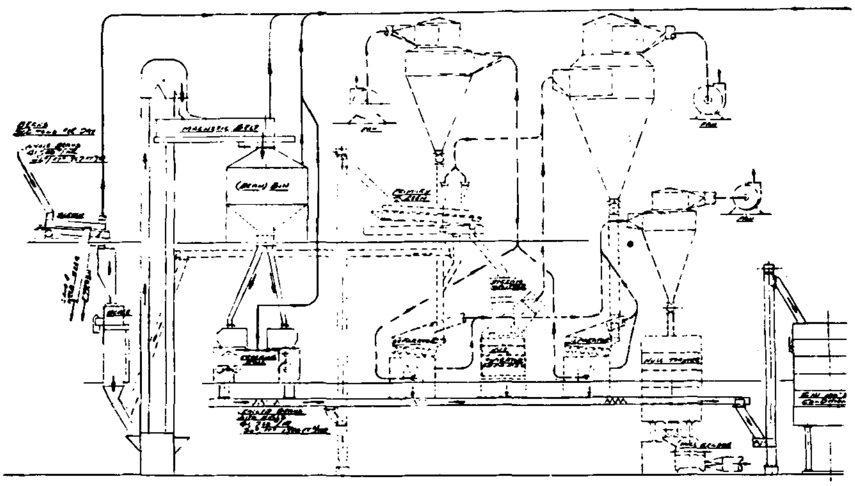

FIG. 5.

ture prior to flaking. Hot cracked soybeans are then flaked to ca. 0.254-0.305 mm thick before solvent extraction of the oil.

If soybeans are to be processed to produce high protein/low fiber soybean meal, a subsequent preparation step is required, as shown in Figure 5. Once the soybeans have been cracked, the hulls must be separated by size and specific gravity. An efficiently operated front-end dehulling system produces a hull stream that has a maximal fat content of 1.5% and it produces a finished meal stream containing no more than 3.3% fiber by weight.

FUTURE PRACTICE

A prediction of future material flow through a mill elevator is diagrammed in Figure 6. A stationary scalping spout could be used on the discharge of the whole bean receiving leg and sized for the same capacity as a receiving leg. The scalping spout separates large foreign material from the soybean stream and passes fine foreign material and whole soybeans on for further cleaning. After scalping, a stationary screen could be used to clean soybeans and remove weed seed, dust and fine foreign material. A single-deck stationary screen would have a variable pitch of 40-50 degrees. Aspirated dust taken not only from the cleaning of soybeans but also from the head of the receiving leg and the unloading pit may be taken to the preparation area together with weed seed and fine foreign material. The separated trash from the scalping/cleaning operation may be refined, and all foreign matter containing oil-bearing material may be returned to the preparation process for oil recovery. Non-oil-bearing, nonmetallic foreign material would be mixed with mill feed.

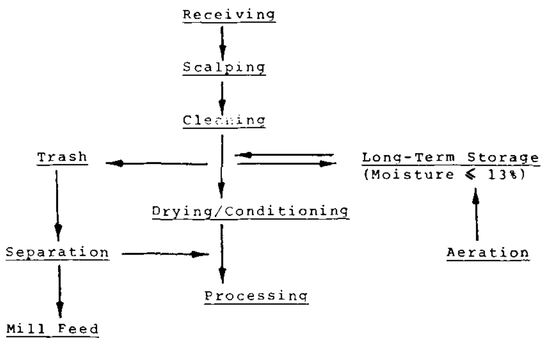

FIG. 6. Future mill elevator flow.

High moisture soybeans may be dried or conditioned to 10-12% moisture and conveyed directly to process without intermediate tempering. It would be essential to add live steam, in very small amounts, to the dry soybeans in order to shrink the hull from the seed. Temporary storage may be used for high-moisture beans, if adequate aeration is available, and the stored beans may be conditioned with boiler stack gases or a closed loop hot air conditioner before going to process.

Cracking rolls or slicing rolls may be used to crack hot soybeans, followed by a partial or total front-end hull removal system. A closed loop air system should be used on the dehulling system equipment in order to minimize heat loss and to control particulate emissions. Hot, dehulled, cracked beans may be flaked without further conditioning and conveyed to the extractor for oil separation. The advantages of the proposed future system are: (a) lower initial capital investment/capacity unit; (b) lower energy cost/capacity unit; (c) lower maintenance cost/capacity unit.

REFERENCES

1. Becker, K.W., Davy-McKee Company, "Processing of Oilseeds to Meal," 1969.
2. Dodge, M.A., Ferrell-Ross Company, private communication, 1980.
3. Eckey, E.W., "Vegetable Fats and Oils," 1954, pp. 504-519.
4. Food and Agriculture Organization of the United Nations, Agricultural Services Division, "Technology of Production of Edible Flours and Protein Products from Soybeans," Bulletin 11, 1971, pp. 5-8.
5. Funk, L., Carter-Day Company, private communication, 1980.
6. Grams, T.L., Chicago Eastern Company, private communication, 1980.
7. Gustafson, E., "Loading, Unloading, Storage, Drying and Cleaning of Vegetable Oil Bearing Material," JAOCS Vol. 53, No. 6, June 1976, pp. 248-250.
8. Mann, W. E., Archer Daniels Midland Company, private communication, 1980.
9. Markley, K.S., "Soybeans and Soybean Products," 1950, Vol. I, pp. 425-500.
10. Mitchell, T., Gold Kist, Inc., private communication, 1980.
11. *National Soybean Processing Association*, "Fourth Plant Operations Symposium," 1960.