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BACKGROUND

Consumer diets in eastern Europe and the Soviet Union are deficient in meat products. Potential demand exists in these counties for feeding soybean meal to livestock and poultry. Quality and handling problems with soybean meal have caused resistance to sales of U.S. meal. These problems are virtually unknown in the United States because most of the soybean meal is consumed domestically within a few weeks of its production. Meal is moved to farms and feedlots in relatively small amounts (i.e. truckload) and long term storage is not necessary.

Pelletizing the soybean meal may be a solution to these concerns. Most of the South American soybean meal sold to the Eastern Block Countries is pelletized. Pellets have the advantages of shipping and handling characteristics similar to the those of grains, reduced waste, and better quality maintenance. The advantages of soybean meal pellets over meal may be great enough to recover the pelletizing cost and increase sales in these markets.

The Minnesota Soybean Research & Promotion Council, the Greater Minnesota Corporation and the United States Department of Agriculture has requested that the University of Minnesota evaluate the economic feasibility of pelletizing Minnesota soybean meal for export through the port of Duluth/Superior to the Soviet Union and eastern Europe. Part of the research is to determine the costs and/or cost savings of pelletizing Minnesota soybean meal. This paper reports the results of part of that research undertaken to determine the cost of pelleting soybean meal.

INTRODUCTION

Soybean meal tends to "set up" or cake in storage and transport vehicles if it is not moved frequently. This characteristic makes the meal difficult to handle without special equipment. Pelleting of the meal improves the flowability of the product. This improves handling and makes it possible to store for extended periods of time. Pelletizing should improve the acceptability of Minnesota soybean meal in foreign markets. The purpose of this paper is to develop engineering cost estimates for pelleting soybean meal.

CHARACTERISTICS OF SOYBEAN MEAL

Soybean meal is the principal protein product coming from defatted soybean flakes which are prepared from soybeans for oil extraction purposes. The meal contains a minimum of 44% protein if hulls are included or 47.5-49% protein if free from hulls. Trading rules require that the type of process used for removing oil (solvent extraction or expeller) be included as part of the name of the defatted meal.

Grinding of defatted flakes to produce meal is done with hammer mills. The specification used by the industry is that all meal should pass a 10-mesh screen with a maximum of 50% passing a 24-mesh screen and a maximum of 1% passing an 80-mesh screen. It means grinding should be done without excessive production of fines to produce medium quality texture. This may help in increasing the pelleting capacity and also in producing good quality pellets.

The following table shows the composition of the solvent extracted soybean meal on a percent dry matter basis.

Table 1: Composition of solvent extracted soybean meal (Feedstuffs, 1988)

Ingredients	44% protein %	48% protein %
Dry Matter (as feed)	89.0	90.0
Crude protein	49.9	55.1
Crude fiber	7.0	3.7
Ash	7.3	6.5
Calcium	0.36	0.36
Phosphorus	0.75	0.75
Potassium	2.21	2.21
Magnesium	0.30	0.30

PELLETING:

Pelleting can be defined as the agglomeration (process of molding into mass) of small particles into larger particles by means of a mechanical process in combination with moisture, heat, and pressure. The main advantage of pelleting is that it improves feed efficiencies and feed handling characteristics. Pelleting increases bulk density, which allows the feed manufacturer to store more product per volume. The increase in density varies, depending on the type of ingredients that are pelleted. For fibrous materials the increase in density will be considerably more than for nonfibrous materials like soybean meal when pelleted. Flowability is also improved when comparing pelleted meal to unpelleted meal. The angle of repose for the soybean meal pellets is 35 degrees as compare to 32 degrees for the raw meal.

Pellets generally are formed with diameters ranging from 10/64 to 48/64 in with a length somewhat longer than the diameter. The largest diameter usually found is rarely greater than 1-1/4 to 1-3/8 in. In most cases where particle sizes smaller than 10/64 in are desired, it is more economical to produce 10/64 in or 12/64 in pellets and then reduce them to the desired size by means of crumbling. Soybean meal pellets are generally 1/4 to 3/8 inches in diameter.

FACTORS AFFECTING PELLETING

Fiber

Fiber is a natural binder but, unfortunately, it is difficult to compress and force through the holes of a die. Usually a high fiber feed produces a tough pellet but results in a low production rate.

Bulk Density

The capacity of the pellet mill increases with increase in the bulk density of the feed. However, the pellet bulk density of both low and high bulk density feed will be about 41 to 42 pounds per cubic feet. When pelleting materials with high density, like soybean meal, the pellet mill has less work to do than when pelleting materials of low bulk density.

Texture

Medium and fine grinds generally will result in higher pelleting capacity and better quality than a coarse grind. Medium and fine ground materials provide greater surface area for absorption of moisture from the steam resulting in better lubrication, also the starting bulk density of medium and fine meal is higher. Coarse grinds have the disadvantage of providing natural "breaking points" in pellets. As pellets are handled, they will tend to break at the surfaces of the coarse particles, creating more fines.

Steam Addition

The steam requirement depends on the moisture content, relative humidity and kind of formulation. High protein feeds, like soybean meal require a great deal of heat but not as much moisture as high starch feed.

PELLETING PROCESS

Feed mash from the pellet mash bin flows into the feeder and conditioner where steam and liquids are added. The conditioned mash then flows into the pelleting chamber where the pellet is formed. The hot pellet then passes through the cooler where it is cooled by air movement from a fan. Fines entrained in the cooling air are separated in a collector and returned to pellet mill to be reprocessed. Cool pellets are discharged from the cooler and pass around, or through, the crumbler depending on the product being manufactured. The product then passes through a screening mechanism where product separation takes place. The acceptable product goes to the finished feed bins while the fines and overs are returned to the pellet mill to be reprocessed. This is the general process of pelleting the feed, however, in case of soybean meal pelleting, only steam will be added in the conditioner.

PELLETING EQUIPMENT AND MACHINERY

Supply Bins

The supply bin must be adequate to store a sufficient quantity of meal immediately ahead of the pellet mill to provide not only continuous pelleting but also continuous operation of the conditioner which provides mash to the pelleting unit. Generally, the bin supply immediately ahead of the pellet mill should consist of at least two bins, each of a capacity not less than 1-1/2 times the capacity of the conditioner used to supply meal to the pelleting unit.

These supply bins should be constructed in such a manner that there will be no bridging or surging. The bin mounted directly over the pellet mill feeder should have two adjacent vertical sides and one of these sides should be at the beginning of the feed screw. The other two sides of the bin outlet should have different slopes to produce a shearing effect in the feed flowing down the sloping sides. That tends to break up arch formations. Whenever possible, one face should have a 60 degree slope to the horizontal while the other should have a 70 degree slope.

Feeders and Conditioners

Thoroughly mixed ingredients, called "mash", are allowed to flow by gravity into a screw type "feeder" which delivers a constant and prescribed amount of meal to a conditioning chamber. The feeder also serves as a seal to control steam in the conditioner from entering the surge hopper above the feeder.

The conditioner is the blending mechanism for any additives being introduced to the feed. It consists of a chamber with an agitator to blend the additives. Here the meal is thoroughly mixed with steam (heat and water) and other desirable liquids such as molasses, sap, and fish solubles. The conditioner length needs to be long enough to bring meal temperature to the desired level and to properly blend the additives. Conditioning is almost universally accomplished by the addition of controlled amounts of steam. Addition of steam supplies moisture for lubrication, liberates natural oils and, in some cases, results in partial gelatinization of starches.

Pellet Mills

The conditioned meal then flows by gravity into the pellet mill die chamber where rollers press the softened mash through holes in a circular die. Stationary knives located outside the circular, rotating die, cut off the shaped, dense pellet at the proper length. Most modern pellet mills use ring type dies turning about two fixed rollers, with the die and rollers mounted in a vertical plane.

Pellet mills are available in a wide range of sizes, from small mills of 20 to 40 hp (1.2 to 2.5 tons per hour, TPH), to large mills up to 700 hp (45 TPH). The inside diameter of the pellet die on the small mill is 12 inches versus 32 inches in a large mill. The throughput capacity of a mill depends on ingredient characteristics such as bulk density of the meal, and thickness and rpm of the die.

All pellet mills incorporate some type of speed reduction device, since die speeds are always less than the conventional motor speeds. Pellet dies must turn fast enough to keep the feed in the pelleting chamber from plugging the mill but slow enough to keep the peripheral speed of the die from causing quality problems. The rpm of the dies generally ranges from 100 to 400. Speed reduction devices include direct coupled gear trains, V-belts, cog belts and a combination of belt and gear trains.

Die thickness is an important factor in determining the quality and production rate of the pellets. For example, a thick die will normally produce a better quality pellet than a thin die, but it will also reduce the production rate as compared to a thin die.

Coolers

From the pellet mill die chamber, the pellets normally flow by gravity into a device for cooling and drying the pellets. Soybean meal pellets will leave the pellet mill at temperatures as high as 190 ^{0}F and moisture contents as high as 17 to 18 per cent. For proper storage and handling of pellets, their moisture content must be reduced to 10 to 12 per cent and their temperature to about 15 ^{0}F above atmospheric temperature. It is accomplished by passing a stream of air through the bed of pellets. This evaporates the excess moisture, causing cooling both by the evaporation of water and by contact with the air.

There are two basic types of coolers used in the pelleting industry, the horizontal and the vertical cooler. The cooler type will often be determined by the plant layout and product mix. Where floor space is limited, the vertical cooler will probably be the most appropriate. Where height is limited, as in a basement location, the horizontal cooler will probably apply.

ESTIMATION OF PELLETING COST OF SOYBEAN MEAL

Electricity Use

Electricity is used for electric motors on conveyors, elevators, distributors, feeders, pellet mills, coolers or dryers etc. and for lighting. Lacking separate electric meters on each system, electricity usage can be estimated by adding the horsepower (hp) of the individual electric motors of the system to determine the total connected horsepower. The following table shows the distribution of the total hp for a typical 200 hp pelleting unit.

Table 2 : Pelleting system connected motor horsepower (Feedstuffs, 1988)

Driven Unit	Motor hp
Feed Conveyor	1.0
Mash Conditioner	7.5
Pellet Mill	200.0
Centri-Feeder	3.0
Cooler (Horizontal)	1.0
Cooler Fan	50.0
Airlock	0.75
Crumble Rolls*	20.0
Bucket Elevator	5.0
Shaker	3.0
Distributor	0.25
Pellet Coater*	6.00
Conveyor	2.0
Distributor	0.25
Total	300.0

* These units may not be needed for the pelletization of soybean meal.

As a rule of thumb; it can be assumed that the horsepower requirement for pelleting soybean meal is 100 hp per 6 tons per hour (TPH) throughput capacity. Another 50 hp (50%) is added for the peripheral equipment (Massengill, 1989). The following calculations are made for the 50 TPH throughput capacity of the pellet mill.

Example Calculations:

Pellet Mill hp = 50 * 100/6 = 833.33 hp.

Total hp = 833.33 + 0.5 * (833.33) = 1249.99 or 1250 hp

Electric power in kW = total hp * 0.7455 / 0.85
= 1250 * 0.7455 / 0.85
= 1096.32 or 1097 kW.

1 hp = 0.7455 kW and motor efficiency = 0.85

Cost of electricity per ton pelleted @ \$0.06 per kWh.
= (kW * \$ per kWh) / tons
= 1097 * 0.06 / 50 = \$1.32 per ton.

Total cost of electricity = \$ 1.32 / ton

<u>Boiler Fuel Use</u>

The cost of boiler fuel depends on the amount of steam required which again depends on many other factors as discussed earlier. The boiler horsepower can be determined by knowing the percent moisture added to the pellets by steam and the throughput capacity.

Boiler Horsepower = F * M / 0.83 * 34.5

where :

F = pounds of feed per hour

M = percent of moisture to be added by steam

34.5 = The amount of water evaporated in one hour at 212 ^{0}F which equals one boiler hp.

0.83 = An approximate correction factor for makeup water at 50 ^{0}F.

For a 50 TPH capacity and assuming 5% moisture addition:

Boiler Horsepower = 50 * 2000 * 0.05 / 0.83 * 34.5 = 174.62 or 175 hp

Thus, at least 175 hp boiler will be required for the pelleting process. The cost of the boiler fuel can be determined by knowing the total Btu/hr and assuming the heating value of the natural gas as 1000 Btu per cu. ft. of gas and cost @ \$ 5 per 1000 cu.ft.

Natural gas required = boiler hp * 33475 * 1.25 / 1000

= 175 * 33475 * 1.25 / 1000 = 7322.66 cu.ft./hr

1 boiler hp = 33475 Btu/hr and boiler efficiency =.75

Cost of the natural gas per ton = 7322.66 * 5 / 1000 * 50 = $ 0.73 /ton.

Therefore,

Total energy cost = cost of electricity + cost of boiler fuel.
= 1.32 + 0.73 = $ 2.05 per ton.

<u>Labor Costs</u>

Labor costs are a function of the wage rate paid, the benefit package provided, the efficiency of the labor (labor-hours per unit manufactured), and the amount of overtime worked.

Example Calculations:

Assumptions : The plant capacity is 50 TPH and it operates one 8-hour shift, 5 days per week. Two persons per shift with total wage (including benefits) @ $13.00/hour per person.

Therefore,

Cost of the labor per ton = 13 * 2 / 50 = $0.52/ton.

<u>Cost of Equipment</u>

Assumptions : The cost of equipment minus boiler is $120,000 per 100 hp, of pellet mill or per 6 TPH capacity (Massengill, 1989).

The installation cost is assumed to be the same as the cost of the equipment.

Cost of boiler including installation is $60,000.

Example Calculations :

Cost of equipment	120000/6 ton * 50	= $1000000.00
Cost of installation		= $1000000.00
Cost of the boiler		= $ 60000.00
Total cost of the equipment :		= $2060000.00

<u>Depreciation and Interest</u>

Assumptions : The life of equipment is assumed as 15 years respectively.

Interest rate is assumed to be 12%.

These assumptions correspond to a capitol recovery factor of 0.15.

Pelleting Plant Cost Estimate

The following calculations consider two different work schedules corresponding to two different yearly capacities for a single plant with a 50 TPH capacity.

CASE I

These costs are based on a work schedule of 200 days per year operating 15 hours per day (two 8-hour shifts). This corresponds to a yearly production capacity of 150,000 tons (about 8 ship loads).

Depreciation and interest on equipment :

= 2060000.00 * 0.15 / 200 * 15 * 50 = $2.06/ton.

Table 3 : Fixed and Variable Costs per Ton for Equipment.

Cost Item	Capacity (tons per year)	
	150,000	345,000
FIXED COSTS :		
Depreciation & Interest on the equipment	$2.06	$0.90
Taxes	0.20	0.20
TOTAL FIXED COSTS	**2.26**	**1.10**
VARIABLE COSTS :		
Labor	0.52	0.52
Maintenance & Repair	0.15	0.15
Dies and rolls	0.50	0.50
Electricity	1.32	1.32
Boiler Fuel	0.73	0.73
Supplies & misc.	0.50	0.50
TOTAL VARIABLE COSTS	**3.72**	**3.72**
TOTAL PELLETIZATION COST WITHOUT BUILDING	$5.98	$4.82

CASE II

The work schedule is assumed to be 300 days per year with 23 hours per day (three 8-hour shifts). This corresponds to yearly capacity of 345000 tons (about 19 ship loads).

Depreciation and interest on equipment :

= 2060000.00 * 0.15 / 300 * 23 * 50 = $0.90/ton.

The above sample calculations show that the fixed costs are very sensitive to the total number of working days and total working hours per day or to the total yearly capacity of the plant.

Other Cost Factors

Building Cost

The above costs do not include the depreciation and interest on the building. Approximately 2500 square feet are required for a 50 TPH plant.

Receiving of meal

These costs may involve the cost of inspection, weighing and unloading of the meal at the pelleting facility.

Storage of meal

It is necessary to account for variations in the supply of meal and/or in the plant operation. In such case at least one week storage should be provided at the pelleting facility. Such storage requirement will be, for

Case I (150000 tons per year) : 15 * 50 * 7 = 5250 tons.
= 262500.0 cu. ft.

Case II (345000 tons per year) : 23 * 50 * 7 = 8050 tons.
= 402500.0 cu. ft.

Storage of pellets

The size of the pellet storage facility depends on the total surplus volume of the soybean meal available in the State. If the port is open only nine months and the supply of the meal is for the complete year, then it is necessary to have at least three months storage capacity. Such storage requirement will be, for

Case I (150000 tons per year) : 15 * 50 * 90 = 67,500 tons.
= 3375000.0 cu.ft.

Case II (345000 tons per year) : 23 * 50 * 90 = 103,000 tons.
= 5150000.0 cu.ft.

REFERENCES:

1. American Feed Industry Association, Inc., Feed Manufacturing Technology III, 1985.

2. American Feed Manufacturers Association, Inc., Pellet Mill Operators Manual, 1982.

3. American Feed Manufacturers Association, Inc., Pelleting Animal Feed, 1982.

4. Feedstuffs, 1988 Reference Issue, vol.60 no.31, July 27 1988.

5. Cooney, G. ,Personal communication, Buhler Miag Inc., Minneapolis 1989.

6. Massengill, Robert, Personal communication, California Pellet Mills, Minneapolis 1989.