

# Maximizing pellet quality during load-out and delivery

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After obtaining the optimum pellet quality in the pelleting/cooling process, and after screening the pellets and possible post-pelleting application of liquids, the final product has been formed. The main goal in the steps that follow is to maintain the desired pellet quality achieved in the previous processes.

Post-processing, pellets are generally stored in finished product silos, are loaded-out in different ways to either the bulk truck or packing into bags, after which the feed is transported to distributors or farmers. These steps will be discussed in this chapter, including the various alternatives available at different stages.

## Finished product storage silos

The theory of minimizing the damage to pellets in the silo goes back to pressure. The physics of pressure in silos can be determined by the following equation:

$$P_i = C \times (A/U \times \mu) \times \gamma$$

$P_i$ —pressure on the product

$C$ —constant

$A$ —surface

$U$ —perimeter/diameter

$\mu$ —friction coefficient of the product against the wall

$\gamma$ —density/specific weight

Ultimately with normal pellets, the equation of pressure goes back to  $(A/U \times \mu)$ . The bigger the

silo, the higher the pressure, and the less friction of the product against the wall, the higher the pressure. Based on this theory, damage to finished pellets stored in silos can be explained.

In order to minimize the damage and to maintain the desired pellet quality, the silo design needs to be considered. Silo design is important to minimize the damage; to guarantee first-in-first-out; and to minimize contamination.

Assuming that the pellets are cooled through and through, and that the temperature of the pellets after cooling is less than 5°C above ambient, no special provisions—such as open-silo decks, isolated silos or galvanized silo plates—are required, as condensation will not occur. In regards to the design, the silo, as well as the hopper needs to be taken into account. However, the hopper design is also partly dependent on the out-loading system (screws, grid slides, etc.).

Choices need to be made between round or square silos, and build-up out of corrugated silo plates or flat-wall silo plates. From a contamination point of view, round silos would be preferred; however, the disadvantage of round silos is that the space available is not maximized, as there is dead space between the different silos (net silo volume is smaller compared to the surface required).

The disadvantage of round or flat-wall silo plates in general is that the pressure build-up in the silos is only directed to the bottom. This leads to a lower friction coefficient of the product against the wall; therefore, a higher  $P_i$  in flat-wall silos than

corrugated silo plates with the same filling height. In this regard, corrugated silo plates will lead to less damage of the pellets (due to a lower  $P_i$ ).

In smooth walled silos the friction coefficient with the walls is lower, and consequently the  $P_i$  is higher, causing more damage to the pellets. The pile planking structure absorbs part of the vertical pressure force, reducing the vertical load and the risk of consolidation of the product and breakage of the pellets. The  $P_i$  in a flat-wall silo can be 2-3 times higher than in a pile planking silo.

On the other hand, the least damage is achieved when pellets all move at the same speed, minimizing the friction between the pellets—which is dependent on the silo wall type as well as the hopper design. Also, round corners will lead to a lower friction coefficient therefore will cause more damage to the pellets in the finished product silo.

In general, it is recommended to limit the height of finished product silos to 15 meters. Otherwise, the falling height of the pellets into the silo will cause excessive damage to the pellets. This is unless special provisions are made in the silos to reduce the falling height of the product. These provisions are normally not used for regular animal feed pellets but only for very sensitive products.

The diameter:height ratio is not important in the case of regular animal feed pellets, but it is important when storing a product, such as a premix in finished product silos in order to avoid segregation. The maximum static  $P_i$  when storing pellets is reached when the height exceeds 2.5 times the perimeter/diameter. This is reached in most of the cases when storing pellets in finished product silos in order to reach the required storage capacity.

The dynamic  $P_i$ , when out-loading pellets, reaches 3-4 times the maximum static pressure, dependent on the out-loading capacity and the diameter-to-height ratio. Ultimately, storage time of the finished product in the silos should not exceed 8 hours, in order to guarantee fresh feed to the animals and to avoid the need for aeration systems, etc.

The hopper design is dependent on the discharge mechanism and out-loading system chosen, as well as the flexibility required in the out-loading section

(mash as well as pellets in the silos, etc.). When using the finished product silos only for pellets—which means that minimizing the damage to the pellets and first-in-first-out are the main goals—the angle of the hopper, as well as the centricity of the hopper are of importance for a proper hopper design. With a proper hopper design first-in-first-out can be achieved, which also results in minimized difference in speed between the pellets, leading to a minimum of fines.

Asymmetric hopper design avoids the chance for bridging, which is less relevant when only pellets are stored. This design allows a difference in speed among the pellets, which results in more fines created, as well as no first-in-first-out.

The outlet might seem a simple thing; however, many silo unloading problems are caused by incorrect hopper design. The hopper must be designed in such a way that it enhances a free and even product flow. In general, it can be said that a good hopper design must feature:

- Steep walls (the steepness is determined by the flow behavior of the product)
- A large outlet opening
- No dead angles (or for bad-flowing materials, have rounded corners inside)
- A smooth surface
- An asymmetric outlet

Expanding hoppers are an option, but they are not required when storing only pellets. As pellets generally have a good flow characteristic, there is no need for agitators, vibrators, pneumatic pads or other devices to avoid bridging. If these devices are installed, there will certainly be a negative effect on the pellet quality, as these devices cause friction—leading to an increase in the percentage of fines. However, in non-traditional feeds and high-fiber rations, some special attention needs to be given to the flow ability of the finished product in pelleted form.

In those cases where products pack together during the filling of the silo, it might be necessary to provide the option for re-circulating the product. In the case of pellets, this is not required if the storage time of the finished product is kept as short as possible.

Normal values for damage to pellets are hard to estimate, as it depends greatly on the physical quality of the pellets (hardness and durability). If good pellet quality is achieved (97% Holmen), the percentage of fines created after screening of the pellets should be kept to a maximum of 1.5-2 % under practical circumstances. This is created in the transport on top of the finished product silos, in the finished product silos, as well as the discharge of the silos. However, the percentage of fines created in the finished product section is strongly dependent on the pellet quality, and the percentage of fines created increases rapidly when the physical quality of the pellets drops.

In order to minimize damage to the finished product in the silos, as well as to minimize operational costs, gravity transport should be used as much as possible. This will allow for minor differences in speed between the pellets, which reduces the friction between the pellets. Of course, storage times should also be minimized. The best balance needs to be achieved between all aspects of feed milling, which means not only pellet quality but also contamination, operational aspects such as maintenance and operational costs, layout of the site, etc.

### **Finished product silo discharge**

Discharge of finished product silos can be done in various ways:

- Slide gates/grid slides (open-close)
- Vibrating bottoms
- Discharge bottoms
- Dosing grid slides
- Chain conveyor/flight conveyor
- Screw conveyor

The preference with regard to maximizing pellet quality during load-out and delivery is to use dosing grid slides, as then the damage to the pellets during transport is the smallest. This is because there is a continuous dosed discharge which minimizes the pressure in the product. In this system, gravity is maximized, while minimizing the  $P_i$ . All other discharge methods described will cause more damage to the pellet.

Discharge bottoms are generally not used for finished product silos containing pellets, and are

only used for products with poor flow characteristics. If there is a horizontal distance between the discharge point and the truck loading point/bagging point, chain conveyors, flight conveyors or screw conveyors can be used. Preference is given to drag flight conveyors, as screw conveyors damage the pellets too much and drag flight conveyors cause less contamination than chain conveyors. Whenever possible, horizontal transport needs to be avoided in order to maximize gravity, minimize contamination, additional investment, and operational costs.

With slide gates (open-close), the out-loading capacity exceeds 100 TPH, and the  $P_i$  during out-loading exceeds 3-4 times the static pressure. This ultimately leads to pressure waves in the silos from the product to the silo walls—which causes more fines. Therefore, dosing grid slides will lead to a lower  $P_i$  and will avoid pressure waves, and ultimately leads to fewer fines. Of course, attention needs to be paid to the design of the dosing grid slides as the moving part should not be within the stored product, minimizing the damage when actuating the dosing grid slide.

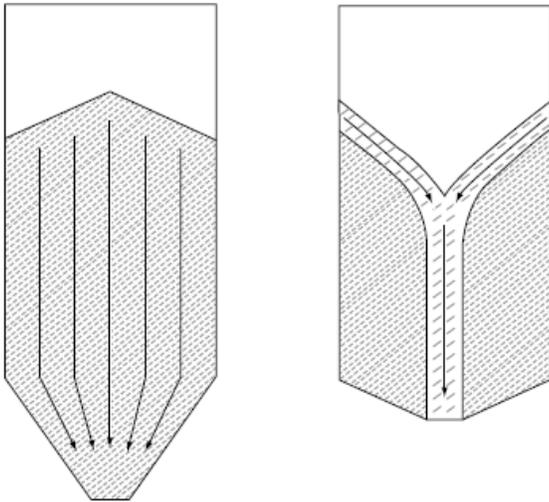
Pressure waves of the product to the silo wall are dependent from the out-loading capacity, as well as the diameter:height ratio. The change of occurrence increases when the diameter:height ratio becomes smaller (a tall silo versus the diameter).

Vibrating bottoms are used when products have poor flow characteristics are stored in the finished product silos, which is not the case with pellets. In cases when vibrating bottoms are used, a slide gate is needed and the vibration will cause fines.

### **Mass flow and funnel flow**

The product's own mass and the developing friction forces will create compression stress and sheer pressure on the bulk solid itself and the silo walls. A correct silo design should therefore be based on stiffness and stability calculations for the silo, as well as a geometric design—which can achieve the desired flow behavior, thus preventing unloading problems. When designing silos, the geometry of the silos should promote mass flow of the product.

**Figure 22-1. Mass flow vs. funnel flow.**



Mass flow is the optimum movement for solids to leave the silo. In a mass flow situation, all material in the silo moves (**Figure 22-1**). Flow occurs without cavities being formed. Segregation as a result of silo loading is almost completely restored in this movement. Other advantages of mass flow are that hardly any product is left behind in the silo and that the first-in-first-out principle is achieved. The latter is very important to maintain fresh product. Mass flow requires a low  $P_i$  in order to minimize the difference between the maximum  $P_i$  (when the product is stored in a full finished product bin) and not under pressure (during controlled out-loading). In that way, the flow of product will be even in the silos. The product will stick together when the  $P_i$  is the high.

Another, but less favorable, silo unloading movement is funnel flow. The bulk solid moves only through the middle part of the silo, forming a vertical channel. An advantage of funnel flow is that the silo walls wear less quickly. However, there are many more disadvantages, such as the last-in-first-out principle, consolidation of the product causing channeling, deterioration or even rotting of the product, un-restorable segregation; decrease of the storage capacity, and fermentation.

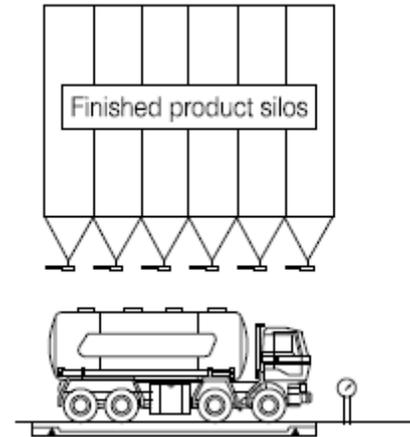
Funnel flow is only acceptable for coarse, granular, easy-flowing solids and in situations in which product deterioration and segregation are not important. Whether mass flow or funnel flow occurs depends on:

- The internal friction of the bulk solid
- The friction on the silo walls
- The design of the outlet hopper

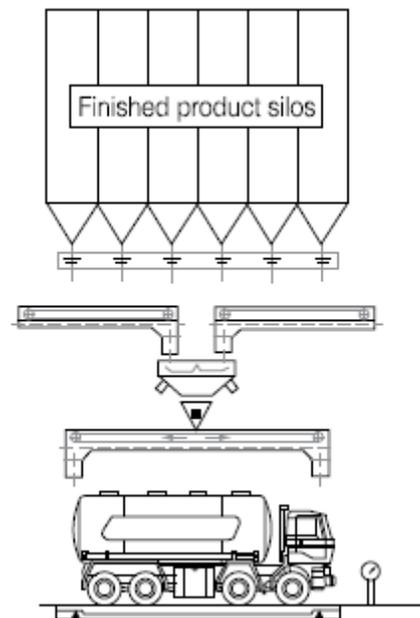
### Bulk out-loading systems

Different options for bulk out-loading are available. Each feed mill will need to decide what method best fits their manufacturing process. Several options for bulk out-loading include the following:

**Figure 22-2. Bulk out-loading directly from silo in the bulk truck with weighbridge.**



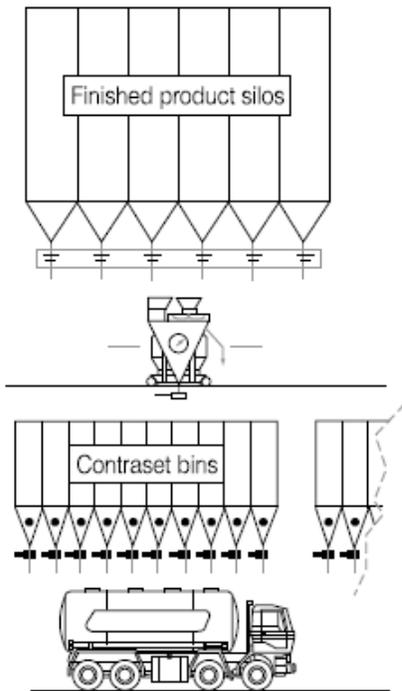
**Figure 22-3. Bulk out-loading using grid slides, belt conveyors, a pellet sieve, a movable belt and a weighbridge.**



The system in **Figure 22-2** has a very simple design. The truck has to be moved after each compartment is loaded. Loading efficiency will depend on the number of different products that will be loaded on the truck. Loading efficiency is generally low due to the time required to move the

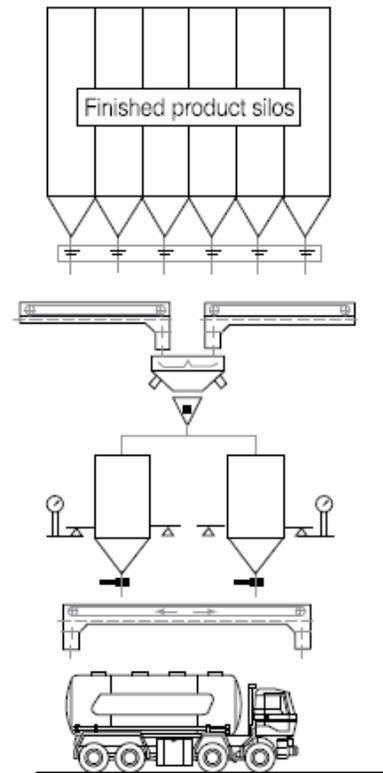
truck. However, the potential for cross contamination is low. The system shown in **Figure 22-3**, does not require movement of the truck during the loading process. While this saves loading time, the use of conveyors, has the potential to create dust, fines, and cross-contamination. The system has a high dosing and weighing accuracy, with no dust/cross-contamination problems. The system tends to be a relatively low capacity bulk out-loading system.

**Figure 22-4. Bulk out-loading using grid slides with sieve and contraset bins.**



In **Figure 22-4**, we see high-capacity out-loading with use of contraset bins. If there are no trucks available, the operator can fill the contraset bins. The number of contraset bins will be based on the number of the trucks each day. A disadvantage to this system is the necessity for standardization of the trucks. Furthermore, the height of the building must be increased or the capacity of the finished product silos decreased in order to accommodate the contraset bins. This high-capacity out-loading system uses a combination of contraset bins and a movable conveyor. One disadvantage of this system is dust and cross-contamination from the use of conveyors.

**Figure 22-5. Bulk out-loading using grid slides, pellet sieve, duo-weighing system and movable conveyor.**



This system (see **Figure 22-5**) is a combination of high-capacity out-loading and flexibility in trucks of different standards. This system is advisable when it is impossible to reach a predictable logistical output system. Disadvantages occur due to dust and cross-contamination when using belt conveyors.

This is a flexible and high-capacity out-loading system. Dust and cross-contamination problems from the use of belt conveyors are the main disadvantage.

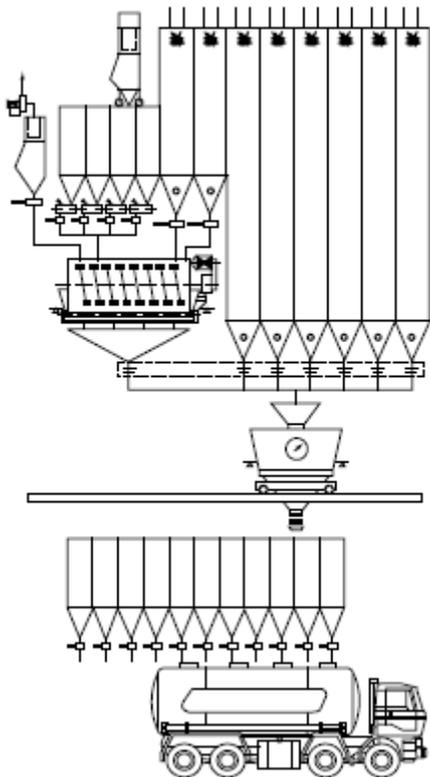
A flexible and high-capacity out-loading system as seen in **Figure 22-6** has the capability to add liquids just before bulk out-loading. This creates increased flexibility for the addition of liquids, especially fat or molasses that may cause bridging in the bins.

This type of system has the potential to blend an unlimited number of formulas to produce maximum flexibility in animal feeding programs. It also allows the possibility to blend single raw materials (cracked corn, wheat, etc) with a concentrate. The system also has the flexibility for separate lines and contraset bins for the different

feeds produced.

This system has cheaper finished product silos with fewer small cells. Concentrated feeds are possible. Through the optimal use of the available capacities of each subsequent process, a higher net output in feed mill capacity can be achieved, along with lower production costs.

**Figure 22-6. Flexible, high-capacity out-loading system.**



Overall, these systems allow for simple processes with simple management and automatization. They are less sensitive and have less of a tendency for breakdown, while being more convenient in terms of operation with lower maintenance costs.

### Feasibility of traditional and modern systems

Traditional systems including weighbridges have estimated loading times per tonne of ready product in the 1.2-1.5 minute range. Modern systems have estimated loading times per tonne of ready product in the 0.2-0.4 minute range. The savings of approximately one minute in loading time per tonne of ready product could be possible with a modern system.

In terms of cost—when estimating the price of hiring a truck and driver per hour—a modern system could save a feed mill with a capacity of 150,000 tonnes approximately 110,000 Euros per year in transport costs. Yearly savings in terms of transport hours (2,500) will result in additional savings in investments of one bulk truck (25 tonnes) for a total of approximately 175,000 Euros.

As stated before, the optimal bulk out-loading system is totally dependent on the individual circumstances of the feed mill. Are standardized trucks used; is flexibility a key issue; can transport be planned (which truck arrives when), etc.? An answer to all the relevant questions will ultimately lead to the optimal out-loading system for each individual circumstance.

In the case of remodels to existing feed mills, constraints generally need to be taken into account with regard to heights available, etc. Therefore, may lead to different choices than when greenfield projects are designed. As each and every situation is different, specialists need to be involved in designing the most favorable bulk out-loading system, as custom-made solutions fulfilling the goals of the individual feed mill are possible.

### Bagging

Although bulk out-loading is common in the more developed countries, a small percentage of production from these areas is sold in bags. This is usually seen with specialty feeds. In less-developed countries, the majority of feed is generally handled in bags. Where infrastructure and economy of scale make bulk handling possible, bulk out-loading becomes quickly economically feasible as compared to bagging off. This varies in every situation of course.

If bagging is considered in a feed mill, a number of questions need to be answered in order to determine the range of bagging off weighers available for the specific situation. First of all, the type of bags used is an important input variable. While paper bags are common in certain parts of the world, plastic or polypropylene bags are used throughout the world. Paper bags are generally used with an automatic closing system, whereby the bags are filled through a spout and the feed itself closes the inlet as the bag

becomes full. The bag is then removed from the filling spout. Plastic or polypropylene bags are generally filled and stitched closed by sewing machine. The bags can be placed automatically on the bagging off weigher or this can be done by hand.

Besides the type of bag used, bag size is an important issue to consider. The size of the bag has an effect on the capacity of the bagging off weigher, and the capacity per hour decreases when smaller bags are used. In the majority of the less-developed countries, 50 kg bags are used. In Europe, however, 25 kg bags are the maximum allowed by the government labor laws.

Filling accuracy also has an effect on bagging capacity. In general, the more time that is allowed for filling, the higher the accuracy that can be achieved. However, there needs to be a balance between accuracy and capacity. An acceptable filling accuracy for bag filling is  $\pm 0.25\%$ . Inaccuracies in filling will lead to either lost revenue (overfilling) or unsatisfied customers (underfilling). In order to ensure that accuracy is achieved, calibration of weighers needs to be done regularly.

To achieve higher capacity levels, bagging off weighers with double weighers (versus single weighers) allow for the required accuracy while still achieving a higher output capacity. The allowable capacity for bagging off is dependent on the operational aspects of the feed mill—i.e., is bagging done in two shifts or one shift while the feed mill is operational in two shifts? Also, the percentage of total production capacity that needs to be bagged plays an important role.

Bagging off weighers used in today's feed milling industry tends to be electronic bagging off weighers instead of the mechanical weighers which were common in the past. Electronic weighers allow for better accuracy to be achieved as compared to mechanical bagging off weighers. Further, the electronic bagging off weighers can be controlled with a separate computer control unit, or can be integrated in the process control system of the feed mill if required.

Bagging off weighers can be generally equipped with three different feeders. These feeders can use

gravity, a belt feeder or a screw conveyor (single or double screw) to move the product along. The feeder that is used depends on the characteristics of the product that needs to be bagged. If contamination is a major concern (as with premix or concentrates), screw feeders are generally used. In most other situations, belt feeders are generally used.

Depending on the design of the feed mill and the required flexibility, the bagging off weigher(s) needs to be able to operate at the same time as bulk out-loading occurs, or the bin(s) on top of the bagging off weigher(s) needs to have sufficient holding capacity to ensure that bagging off can continue while filling a bulk truck. In certain situations, the selection can be made for a number of finished product silos that are used for bagging off only where the other finished product silos are used for bulk out-loading. All these set-ups are custom-made depending on the circumstances the feed mill is operating under.

Farmers' changing demands, strategic objectives and commercial interests will determine the design of the process layout. Legislation in different countries can also influence the technologies applied. As situations are different for every mill, there is not a single standard concept. The needs of the mill should be the starting point for designing an installation. This allows flexibility, for today and for the future.

*This content was edited and reviewed by Dr. Charles Stark, Jim and Carol Brown Associate Professor of Feed Technology at Kansas State University, Dr. Adam Fahrenholz, Assistant Professor of Feed Milling at North Carolina State University, and Dr. Cassandra Jones, Assistant Professor of Feed Technology at Kansas State University.*