# Matching product to cooling process

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Moisture is added in the pelleting process to the meal, both in the mixer and the conditioner. In the mixer, moisture is added to reconstitute moisture lost during grinding and also comes in the form of other liquid ingredients, such as liquid amino acids. Adding water in the mixer is an important step. It helps to raise the moisture and temperature when added as steam during conditioning. As the hot, moistened meal is pressed out, the temperature is elevated further due to the frictional forces exerted. The moisture content of the pellets varies depending on the product design, but it can be as high as 17%. In the end, the excess moisture content needs to be removed in order to increase the shelf life and the pellet hardness.

Cooling must be done as soon as the pellets leave the die. An efficient cooler should be able to reduce the product temperature to within 5-8°C of ambient temperature. As the air is forced through the pellet bed, it is heated—thus increasing its capacity to pick up moisture. The hotter air then removes moisture that has condensed on the surface of the pellets.

The process of removing moisture with unsaturated air is known as evaporative cooling. When non-saturated air is passed through, it picks up the moisture and at the same time cools the pellets. As more air is passed through the pellets, more moisture from the core of the pellet is drawn to the surface, until almost all the moisture added upstream is removed.

Product size, in particular the diameter, is an important factor to consider when evaluating the cooling capacity of the cooler. As pellet diameter increases, the amount of air required to cool the product must also increase. It is also important to increase the dwell time in the cooler for the same airflow as the diameter of the pellet increases. **Table 12-1** shows the relationship between pellet size, retention time, product throughput and airflow required to cool the pellets.

In order to better understand the cooling process, it is important to take a closer look at the energy balance and the thermodynamics involved. Animal feeds can have a specific heat of about 2.0 kJ/kg°C. The specific heat will depend on the composition of the ingredients in the formula. For example, we have 1,000 kg of a pelleted poultry feed with a specific heat of 2 kJ/kg°C. Air has a specific heat of 1 kJ/kg°C.

**Table 12-1.** Pellet size, retention time, product throughput, and airflow requirements.

| Pellet diameter, mm | Airflow, m3/hr | Residence time, min |
|---|---|---|
| 2.0 | 1,200 | 6-8 |
| 2.4 | 1,200 | 6-8 |
| 3.0 | 1,500 | 6-8 |
| 3.5 | 1,500 | 6-8 |
| 4.0 | 1,500 | 8-10 |
| 4.5 | 1,600 | 8-10 |
| 4.7 | 1,600 | 8-10 |
| 5.0 | 1,600 | 10-12 |
| 6.5 | 1,600 | 10-12 |
| 8.0 | 1,600 | 12-14 |
| 9.5 | 1,860 | 12-14 |
| 12.5 | 1,860 | 14-16 |
| 16.0 | 2,100 | 14-16 |
| 19.0 | 2,100 | 16-18 |

In this example, we want to know how much moisture can be removed by air alone, and if the volume of air is enough to cool and dry the pellets to safe levels.

Assumptions:

- Initial pellet moisture content: 16%
- Energy required for 1 kg water evaporation: 2,500 kJ/kg
- Mass flow rate of air: 1,500 $m^3$/hr
- Mass flow rate of pellets: 1,000 kg/hr
- Specific heat of air: 1 kJ/kg°C
- Specific heat of pellets: 2 kJ/ kg°C
- Temperature differential of air: 45°C when heated by pellets – 25°C ambient = 20°C
- Temperature differential of pellets: 80°C as hot pellets - 30°C when cooled by air = 50°C

First, we must calculate the energy content of the pellet:

Energy content of the pellet = pellet mass flow rate × pellet specific heat × pellet T differential
*1,000 kg/hr × 2 kJ/kg°C × 50°C = 100,000 kJ/hr*

Next, we can calculate the quantity of moisture in the air that is available for evaporation:

Energy from the hot pellets to heat air = air mass flow rate × air specific heat × air T differential
*1,500 $m^3$/hr x 1 kJ/kg°C × 20°C = 30,000 kJ/hr*

Total energy left to evaporate the water =
*100,000 kJ/hr – 30,000 kJ/hr = 70,000 kJ/hr*

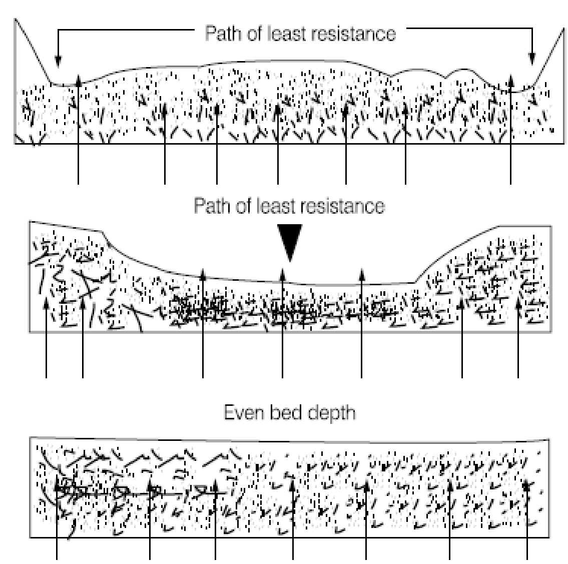
Total water evaporated =
*70,000 kJ /hr ÷ 2,500 kJ/kg = 28 kg of $H_2O$/hr*

In this case, 2.8% of water was removed from the pellets per hour (28 kg/hr ÷ 1,000 kg/hr × 100), leaving the pellets with a final moisture content of 13.2% (16 - 2.8 = 13.2%). Clearly, the changing of other variables will alter the quantity of moisture removed. Realistically, changing the pellet specific heat, initial pellet moisture content, or air moisture content, 2 - 4% moisture can be removed from pellets. If air is too dry when it enters the pellet cooler, it may cause the pellets to lose more moisture than the target, resulting in "shrink" losses. In this case, the excessive loss of moisture can be controlled by reducing the airflow via an air dampener or reducing the residence time in the unit. In any case, it is important that pellets leaving the cooler be no more than 5°C above ambient temperature. If the pellets are too hot when bagged, this may cause condensation on the surface of the pellets that, in turn, will lead to molding—thus reducing the shelf life of the product.

**Cooler efficiency**

The cooler efficiency depends how evenly the airflow is passed through the bed of product. Uneven bed distribution produced as a result of poor pellet dosing to the cooler may result in pellets with uneven moisture. Air will flow through the path of least resistance (**Figure 12-1**) or the valleys formed in the bed. If most of the air flows through these valleys, the pellets therein will be drier than the pellets in the peaks (more resistance to airflow). To correct this, pellets must be evenly distributed along the bed (horizontal cooler) or dosed uniformly in the whole area (vertical counterflow coolers).

**Figure 12-1.** Airflow movement in cooler beds.



In counterflow coolers it is common to find a rotating arm that helps to keep bed depth even (see **Figure 12-2**). A disadvantage of such a device is that it can create more fines as it passes through the bed of pellets. To correct this problem, some manufacturers have come up with PLC-controlled dosing conveyors that rotate and at the same time move in the horizontal axis. This allows the unit to fill at every possible corner of the vertical counterflow cooler and produce a very even bed of product without imparting mechanical energy or causing pellet breakage.

**Figure 12-2.** Counterflow cooler with rotating arm.

Pellet diameter is also a key factor in how well the pellets will cool and dry. Larger diameter pellets will require longer dwell times in the cooling unit to allow the moisture to travel from the core to the surface. Also, the heat transfer from the core to the surface is much slower. This is why smaller pellets cool and dry faster than larger diameter pellets. Smaller pellets also have more surface area of contact with the airflow, thus better cooling and drying efficiencies. In general, cooler capacity increases as pellet diameter decreases. In the pellet mill, pellet diameter decreases as the capacity of the mill decreases.

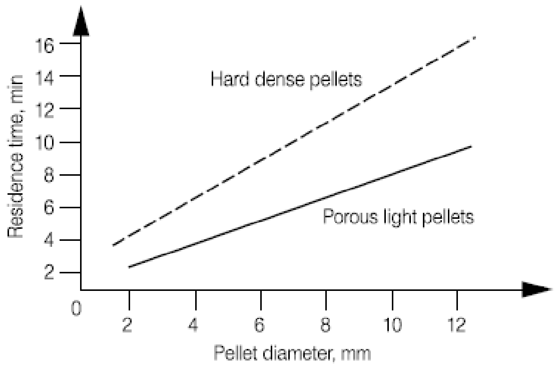
In some feed mills, fat is added to the hot pellets as they exit the pellet mill. The fat that coats the pellets creates a barrier for moisture removal during the cooling process. Also, if too much fat is added and the pellets are brittle, clumps of fat and fines can be formed, inhibiting airflow through the bed of pellets. It is therefore recommended to allow for the fat addition after cooling and after fines have been removed, just before bagging.

Pellet bed depth is also an important factor to consider in how the cooler will perform. In counterflow coolers, the bed depth can be adjusted to a specific residence time. These units come with low and high depth sensors that can be used in PLC systems to control the dwell time. For larger diameter pellets, the bed depth will be increased to increase the residence time and provide the right cooling and drying. The airflow must be properly balanced to achieve proper cooling conditions. If the bed depth is too deep, it may restrict the flow of air and thus reduce the cooling efficiency. In this case, the manufacturer should ensure adequate airflow that matches the production rate of the pellet mill for the maximum residence time. In horizontal coolers, the bed depth is also important and will vary depending on the pellet diameter. For smaller pellet diameters, it is common to have 15-17 cm of bed depth, and this can increase to 23-24 cm for the larger diameter pellets.

Pellet porosity will also affect cooling efficiency. Hard, dense pellets will take a longer time to cool and dry than pellets that are porous for the same pellet diameter. As the pellet hardness and diameter increase, the required residence time in the cooler also increases as shown in **Figure 12-3**.

It is typically recommended to use between 1,300-1,500 cubic meters of air per metric tonne of pellets. This will vary with the type and design of the cooler. The air speed should be sufficient to avoid dust settling in the cooling ducts. Air speeds above 25 m/s can result in fines being blown out of the cyclone.

**Figure 12-3.** Pellet hardness and diameter vs. residence time in the cooler.




Air temperature in the duct system needs to be as high as possible to avoid condensation. The hot air will carry the moisture out into the exhaust without the opportunity for it to condense in the piping system. If condensation occurs, fines can be trapped and form a crust of material which can mold and cross-contaminate the fines that could be re-routed to the pellet mill. It is therefore recommended to set the exhaust air at around 40-60°C.

Horizontal coolers are equipped with perforated pans or trays. The design and size of the orifices in the pans vary between manufacturers. The objective of the orifices is to allow enough air volume to pass through the pellets. Airflow through the trays can be interrupted if the orifices become clogged up with fines. Therefore, it is critical to keep the pans clean. Pellets should also be distributed evenly across the pans and the speed adjusted to match the throughput of the pellet mill. If the cooler pans are run too fast, the pellet distribution and bed depth will not be adequate, causing uneven moisture distribution in the pellets.

**Vertical coolers**

Vertical coolers are simple in design and are considered low-maintenance units because they have few moving parts. They are basically a tower divided into two compartments with a plenum chamber in the middle separating the two columns of product. The pellets are fed from the top and exposed to high-speed air that is pulled through the columns by a fan connected to the plenum.

The product depth is not even in both columns; which may cause air to flow at a higher speed in the areas of least resistance. An advantage of this type of cooler is the small footprint and ease of operation. However, these coolers are known for having blockage problems, as pellets tend to bridge, and more so if pellets are high in moisture or too soft.

**Horizontal coolers**

These units are recommended for soft, moist or delicate pellets. They are less prone to compaction, but a disadvantage of these units is the large footprint requirement and high maintenance costs associated with all the moving parts.

Depending on the space availability, horizontal coolers can be built as single-, double- (**Figure 12-4**) or triple-pass. The single-pass has only one moving apron which discharges the pellets at the end opposite to the intake. Double-pass units are shorter, with two decks equipped with a moving apron. Pellets fall from the top deck to the bottom one and the discharge can be underneath the inlet. If not properly designed, their energy costs may also be higher, because they require more air volume per unit area than vertical or counterflow units.

**Figure 12-4.** Horizontal cooler.

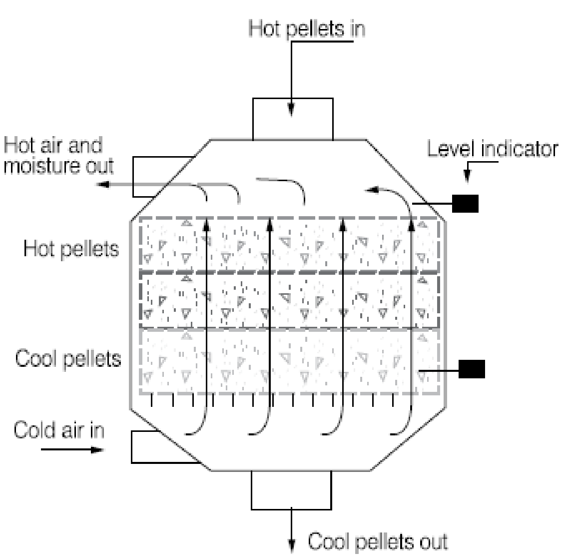
**Counterflow coolers**

As with the vertical cooler, counterflow coolers (**Figures 12-5** and **12-6**) require little space and maintenance. Somewhat similar to vertical coolers, they are fed from the top via an airlock. They require a properly-designed spreader to distribute in-coming pellets evenly. Discharge is automatic when the pellet bed reaches the level indicator that actuates the slide gates. The discharging gates are designed to lift the pellet bed, thus loosening them.

At the same time, the discharge gate opens, allowing the pellets to flow through without pinching them. The gap is adjusted to best match the pellet diameter. In contrast to vertical coolers, where ambient air is drawn from the sides, this cooler passes air through the bottom, thus the term "counterflow," or opposite of the flow of the pellets.

**Figure 12-5.** Counterflow cooler.

**Figure 12-6.** Interior of counterflow cooler.




**Maintaining the cooling system in review**

1. Pellets coming out of the cooler should be 5-6°C above ambient. If the pellets are hotter than desired, the operator must check the speed of the unit if it is a horizontal cooler, or the high level indicator in the case of a counterflow cooler, to ensure adequate residence time.

2. Bed depth or filling should be checked periodically to ensure that the cooler will draw air correctly. A vertical cooler should be completely filled to work correctly. The horizontal cooler also must have a complete bed fill across its width to operate efficiently. Unfilled areas of the trays will allow more airflow through them and less in the trays with pellets, resulting in poor cooling efficiency.

3. The cooler must be checked periodically for deposits or build-up that may have occurred during the time in operation. It is common to find built-up material that has dislodged from the pellet mill, clogging the trays of the horizontal cooler.

4. Periodical inspections of the fans, cyclone and piping should be conducted to ensure that no build-up has formed inside. The build-ups can be reduced if the fan is allowed to run for longer periods after the cooler has been emptied. By doing so, the air in the system will achieve the same temperature as the air drawn in, and this will reduce the chances for material build-up and condensation.

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