

Cooling of Extruded, Dry Pet Foods
Paul Tedman, PE
Extru-Tech, Inc. Sabetha, KS

One of the critical processing steps in the production of extruded, dry pet food is cooling. The cooling step is required after the drying and liquid-coating processes to remove excess heat. If enough heat is not removed, condensation can occur in the product storage bins or in the product package. This article will discuss the major change in dry pet food that has prompted a change in the method that pet food needs to be cooled. The article will also review horizontal and vertical cooler designs, typical processing conditions, and how much cooling is required.

Changes in Pet Food

In the last 10 to 15 years, product changes have caused the cooling process to be redesigned in most pet food production facilities. In the early stages of pet food production, specifically dog food, fat addition levels applied at the coating process were usually less than 10%. The cooling step was normally done before the coating process, as the typical plant flow was extrusion, drying, cooling, coating, storage and packaging. The pre-cooled product would satisfactorily absorb the fat added in the coating system, and the additional heat added from the fat was usually not sufficient to cause storage problems.

As producers began to make dog food with higher levels of added fat, problems were encountered in the coating process. The cool pet food would not absorb the high levels of fat, resulting in pet food with large amount of free fat on the external surface. It was

quickly discovered that if the pet food was coated while it was warm, it would absorb the fat much more effectively. The major problem this created was that most plants were not designed to cool the product after the coating system. Since that time, some plants have been modified to incorporate the cooling process after the coating process. The majority of the new plants being built today are designed to cool the product after the coating process.

Types of Coolers

Most pet food production systems built prior to 1990 commonly incorporated a horizontal cooler (Figure 1) between the drying and the coating process. These coolers were normally an extension of the dryer, which is often referred to as a combination, horizontal dryer-cooler. Although horizontal coolers can be arranged as stand-alone machines, it is more common to see them included as an integral part of the dryer. Incorporating the cooler into the main body of the dryer is a very cost-effective method because the capital investment is reduced compared to a stand-alone unit. In addition, the heated air recovered from the cooling process can be used as make-up air in the dryer, making the overall operation quite efficient.

The general design of a horizontal cooler consists of a perforated conveyor on which the pet food is uniformly distributed up to depths of 4 to 12 inches. The conveyor is sized with sufficient length and width to provide ample retention time to cool the product.

Ambient or chilled air is pulled through the product bed with a centrifugal fan to remove the heat.



Figure1: Illustration of a combination horizontal dryer/cooler.

Horizontal coolers do not perform well when trying to cool post-fat coated pet foods due to the amount of free fat on the external surfaces of the food. The free fat, along with fines present in the product, will readily plug the perforations in the conveyor. Once the perforations are plugged, the airflow through the product bed is reduced, which will result in inadequate cooling. As a result, most new facilities, as well as many existing facilities, have switched to vertical coolers rather than horizontal coolers.

Vertical coolers, like horizontal coolers, have been used in the feed industry for many years. There are many different types of vertical coolers, but all function in a similar manner. Figure 2 illustrates a typical vertical cooler. The product continuously enters through the top of the cooler through a rotary valve or airlock. The product is distributed into a square or round storage vessel where it can be held for a specified retention period. When the level of the product reaches a predetermined level in the storage vessel, product is discharged from the cooler until a specified low level is reached. At that point, the discharging is stopped until a high level is again reached. There are several different designs of discharge mechanisms, depending on the manufacturer, used to discharge the

product from the cooler. Ambient or chilled air is drawn through the product bed via a centrifugal fan to cool the product. Product depths are usually much deeper in a vertical cooler compared to a horizontal cooler, with depths often exceeding 3 feet. The increased product depth causes the air pressure drop to increase, which means the power requirement for the fan is more when compared to a fan used on a horizontal cooler.

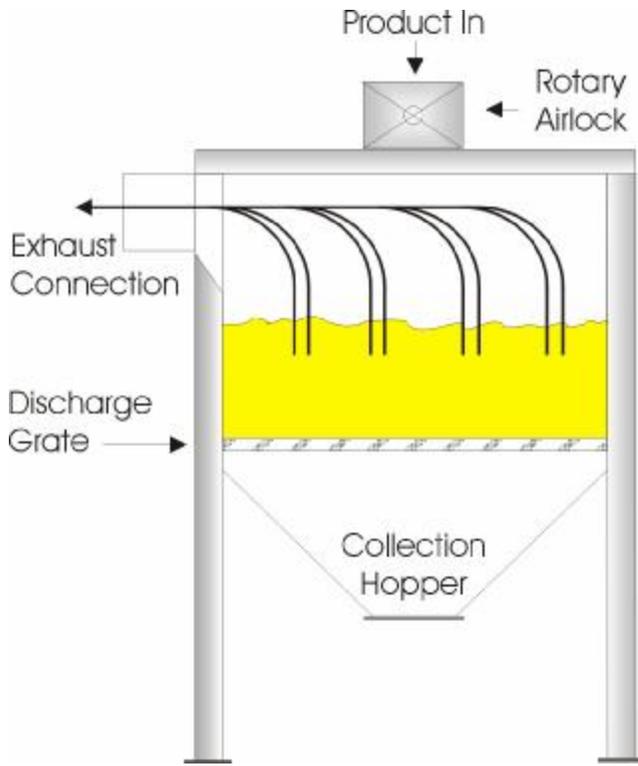


Figure 2. Typical vertical cooler arrangement.

Vertical coolers are becoming widely recognized as the standard cooling device in pet food manufacturing because of the many advantages they offer over horizontal coolers. Probably the single most decisive reason that the vertical cooler is selected is because it will perform satisfactory with pet food that has been coated with high levels of fat.

| | Horizontal Coolers | Vertical Coolers |
|----------------------|--------------------|------------------|
| Capital investment | - | + |
| Operating Cost | + | - |
| Efficiency | - | + |
| Required Floor space | - | + |
| Sanitation | - | + |
| High fat products | - | + |
| Very large products | + | - |
| Small particles | + | - |

Figure 3. Advantages (+) and disadvantages (-) of horizontal and vertical coolers. Horizontal cooler is considered to be a stand-alone unit.

Figure 3 lists some of the advantages and disadvantages of horizontal and vertical coolers. One of the advantages the horizontal cooler has is that it can handle very large products, such as extruded bones, without causing damage to the product. The horizontal cooler also works well for very small products, such as particles less than 2.5 mm in diameter. Because it is difficult to get airflow through a deep bed of very small particles, the product can be spread out very thin on the conveyor of a horizontal cooler, allowing air to pass through the product much easier.

The advantages of the vertical cooler, in addition to handling high fat pet food, is that it usually takes up less floor space than that of a stand-alone, horizontal cooler. The vertical cooler is designed to hold the product to greater depths than in a horizontal cooler, which ultimately results in less required floor space for the machinery. However, vertical coolers can be much taller than horizontal coolers, requiring much more vertical space.

Extru-Tech, Inc. offers a vertical cooler (US Patent Number 5,906,482) which is specifically designed for cooling extruded pet foods (Figure 4.) Product enters the top of the cooler via a rotary airlock. There is no internal discharge grid, which minimizes product breakage. The cooler is round in design, which makes it easier to evenly distribute the product compared to a square design. A significant portion of the internal cone of the cooler is perforated, which allows air to be drawn through the product. Due to the greater working depths in the cooler, the fat has time to absorb into the pet food before it reaches the perforations. As a result, plugging of the perforations is not a problem.

Around the outside of the perforated cone is a secondary cone, which serves as an air plenum and is where the cooling air enters the cooler. The advantage of the air plenum is that it can be directly connected to a ducting system, allowing for outside, chilled or filtered air to be used in the cooling process.

After the air is drawn through the product, it exits through the top of the cooler. The exhaust system consists of a centrifugal fan and a dust collector.

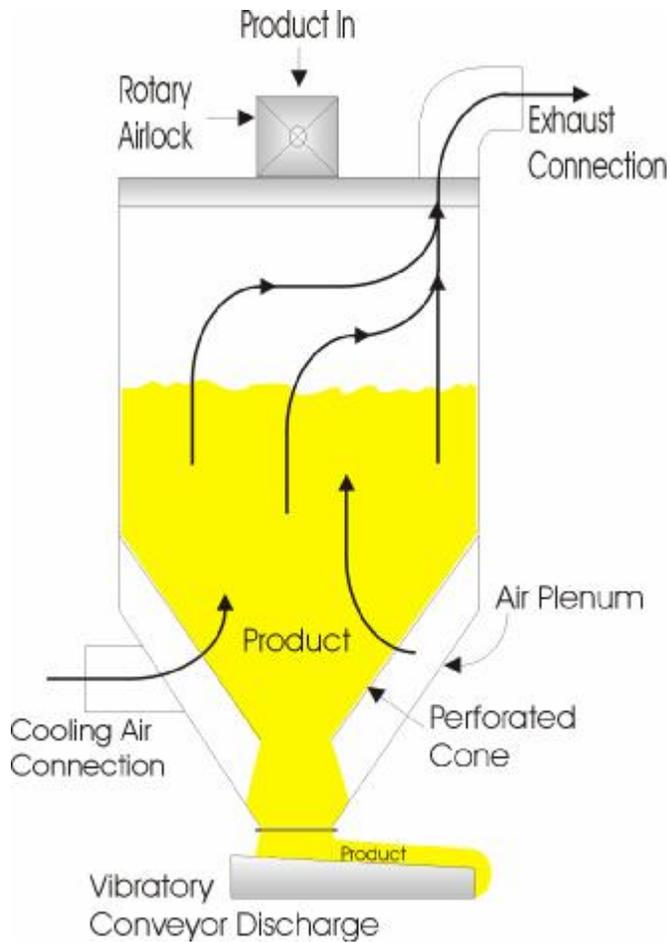


Figure 4. Illustration of a vertical cooler manufactured by Extru-Tech, Inc.

Product is discharged from the cooler with a vibratory conveyor. The vibratory conveyor is the preferred method as it is easy to clean and maintain, and product breakage is minimized. The coolers can be constructed of carbon steel or stainless steel, with stainless steel being the most common construction material.

Due to the design of the cooler, it is impossible for air to bypass the product as long as the product level is maintained in the normal operating range. Because air cannot bypass

the product, the ratio of the volume of air to the product throughput rate is quite low (CFM/Ton). In most cases, the exhaust air volume can be reduced to the point where the exhaust air temperature is equal to the incoming product temperature. This reduces the amount of exhaust air and minimizes the power requirement of the exhaust fan.

Typical Processing Conditions

The pet food temperatures directly after the exit of the dryer will generally range from 140 to 170• F. In some cases, where the food is dried to a very low moisture content, the temperature will be higher. After exiting the dryer, the food is usually conveyed to a screener where the fines and over-sized particles are removed from the main stream. After screening, the pet food is usually coated with fat. The pet food will flash a significant amount of heat as it is being conveyed from the dryer to the screener and to the fat-coating system. It is not uncommon to see product temperatures dropping 40• F before reaching the coating system. The temperature of the pet food after the coating system will depend on the amount of fat that is added. High fat additions will cause the temperature to rise due the temperature of the heated fat. Typical product temperatures at the exit of the fat-coating system will range from 100 to 130• F. From the coating system, the product is conveyed to the cooling system. The cooler must remove sufficient heat to avoid condensation problems in the storage bins and the final package. Safe storage temperatures are discussed in more detail in the last section of this article.

The required retention time to cool a product such as pet food is dependent on three variables: 1) The ability of the product to conduct heat, which is referred to as the

coefficient of thermal conductivity, 2) The geometry of the particle (this would include the surface area and thickness), and 3) How close the temperature of the product needs to be to the temperature of the air which it is being cooled with. Typical cat and dog food can be properly cooled with 10 to 15 minutes retention time.

The amount of cooling air required is a function of how much heat needs to be removed from the food to lower the temperature to a safe level. The air will only remove heat from the product as long as there is a temperature differential between the air and the product. The maximum temperature of the air will equal the temperature of the incoming product. However, chilled air can be used. This will allow more heat to be carried away with the air, which can lower the amount of air volume required. Chilled air also allows the product to be cooled to lower temperatures. Most cooling systems will require 600 to 1200 cubic feet per minute (CFM) of air per ton of finished product in order to accomplish adequate cooling.

How Much Cooling is Required

Condensation occurs when an air-water vapor mixture is cooled to or below the corresponding dew point temperature. Figure 5 illustrates the relationship between ambient air temperature, relative humidity and dew point temperatures. As can be seen in the table, as the relative humidity approaches 100%, the dew point equals the ambient temperature. So at very high relative humidity, only a slight amount of cooling of the ambient air will cause condensation to form.

At 30% relative humidity, there is a much larger differential between the ambient air temperature and the dew point temperature. At 120• F ambient air temperature, the corresponding dew point is 80• F. At 70• F ambient air temperature, the corresponding dew point is 37• F. So at lower relative humidities, larger temperature changes can

| Dew Point Temperatures (F) | | | | | | | | | | |
|-----------------------------|------|-----|-----|-----|----|----|----|----|----|-----|
| Relative Humidity | 100% | 120 | 110 | 100 | 90 | 80 | 70 | 60 | 50 | 40 |
| | 90% | 116 | 106 | 96 | 87 | 77 | 67 | 57 | 47 | 37 |
| | 80% | 112 | 102 | 93 | 83 | 73 | 64 | 54 | 44 | 34 |
| | 70% | 107 | 98 | 88 | 79 | 69 | 60 | 50 | 41 | 31 |
| | 60% | 102 | 93 | 84 | 74 | 65 | 56 | 46 | 37 | 27 |
| | 50% | 96 | 87 | 78 | 69 | 60 | 51 | 41 | 32 | 23 |
| | 40% | 89 | 80 | 71 | 62 | 54 | 45 | 36 | 27 | 17 |
| | 30% | 80 | 72 | 63 | 54 | 46 | 37 | 28 | 19 | 10 |
| | 20% | 68 | 60 | 52 | 44 | 35 | 27 | 19 | 10 | 1 |
| | 10% | 49 | 41 | 34 | 26 | 18 | 10 | 2 | -6 | -15 |
| | 120 | 110 | 100 | 90 | 80 | 70 | 60 | 50 | 40 | |
| Ambient Air Temperature (F) | | | | | | | | | | |

occur before the risk of condensation occurs.

Figure 5. Dew point temperatures for range of ambient air temperatures at various relative humidity levels.

The above information can easily be applied to the cooling of pet food to determine if adequate cooling is being done before storage or packaging. When pet food is stored in bins prior to packaging, the free air in the bin will be heated by the food until equilibrium temperature is reached. If the pet food is still warm, it is also possible for moisture to continue to evaporate from the food. This can create a condition where the free air in the top of the bin is warm and moist. By measuring the temperature and relative humidity of the air in the bin, the corresponding dew point temperature can easily be determined from the data in the chart.

If the outside of the bin (assuming it is not insulated) is subjected to temperatures equal or below the dew point temperature of the internal air, condensation will occur on the inside of the bin. Condensation will form on the internal walls and will drip down and contaminate the food.

In the case where pet food is packaged on-line, it is usually stored in a warehouse directly after packaging. In many cases, warehouses are maintained at much lower temperatures than the processing areas. If ambient air is used to cool the pet food, this means there will be a significant temperature difference between the product and the warehouse.

The temperature of the air in the package will equilibrate to the temperature of the product. Again, by measuring the air temperature and the relative humidity in the package, the corresponding dew point can be determined. If the warehouse temperature is at or below the dew point temperature, a risk of condensation exists.

In a lot of cases, the product will spend very little time in the warehouse and will be loaded directly on a truck. In this case, consideration should be given to the temperature that the pet food will be exposed to during transportation.

A general rule of thumb in cooling is that the pet food temperature should be cooled within 10• F of the temperature that the package will be exposed to during storage or transportation. This may mean in some cases, such as during the winter months, that

outside or chilled air will have to be used in order to lower the temperature of the product to safe levels. During the warmer periods, ambient air is usually satisfactory.

Summary

A lot of changes have occurred in the area of cooling in the last decade, and future changes are inevitable as new products are developed on a daily basis. For now, vertical coolers seem to be the preferred method of cooling pet food, mainly due to the high levels of fat being applied in the coating process.

