Atmospheric conditioning

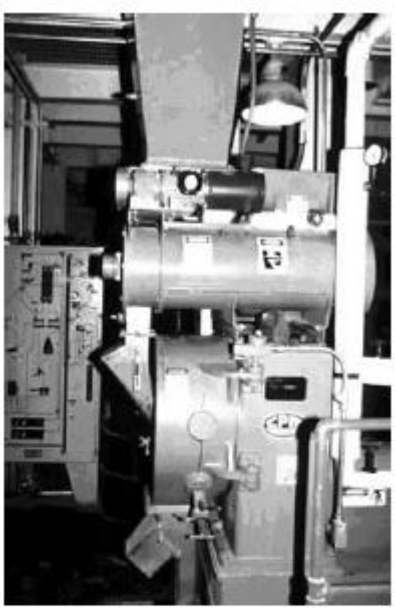
BY KEITH C. BEHNKE, PH.D.

REVIEWED AND EDITED BY ADAM FAHRENHOLZ, CHARLES STARK, AND CASSANDRA JONES

The typical conditioner, commonly associated with a pelleting system, is referred to here as an "atmospheric conditioner" (see **Figure 9-1**). As the name implies, these conditioners operate under atmospheric pressure and are typically exposed to ambient conditions. As a rule, the atmospheric conditioner is basically a single cylinder with an agitator shaft. The dimensions of the cylinder vary with manufacturer, but will range from 38-76 centimeters in diameter and 1.5-4.6 meters in length. The agitator shaft is usually drilled to accommodate several picks (paddles) that can be adjusted or replaced as needed.

The function of the conditioner is to provide for the intimate contact and mixing of steam with the pellet mash. An understanding of how steam and pellet mash interact is critical to the understanding and management of a pelleting system.

Figure 9-1. Pellet mill equipped with a single-pass conditioner.



Steam is used in the pelleting process primarily because of its unique ability to carry and transfer heat through condensation. If only moisture was needed to optimize the pelleting process, a hose attached to a faucet would be a much more economical source than steam. Similarly, if heat was all that was needed, a gas-fired burner would be cheaper than a boiler. However, what we need in the conditioning process is a great deal of heat and moisture targeted at a very precise location—namely, the surface of each particle in the pellet mash. Steam is the most practical way to do this.

As the relatively-cool mash particles are placed in close contact with the steam, the heat from the steam is transferred to the particle, causing its temperature to rise. For each 0.28 kWh of heat (at 0 psig) transferred from the steam to the mash, 2.2 kg of water is condensed onto the surface of the mash particles. This phenomenon of condensation is not unlike the condensation of water vapor from humid air to the surface of a cold drink can. If this concept is well understood by the reader, a good understanding of the atmospheric conditioning process is near at hand. This is the most basic process that happens during conditioning.

Once the condensation to liquid takes place on the surface of the particle, both the heat and moisture begin to migrate into the particle because of a moisture gradient difference between the surface and the interior of the particle. This concept follows the age-old principle of diffusion where there is movement (in this case, heat and moisture) from areas of high concentration to areas of low concentration. The heat supplied by the condensed steam provides the energy to drive the migration.

Because grains, protein meals and other common ingredients are typically good insulators (low heat transfer coefficients), the process of heat and moisture migration is relatively slow. This brings into focus issues related to optimum atmospheric conditioning—i.e., mash particle size and retention time.

Mash particle size

If the above description of relatively-slow heat and moisture migration is true, it is logical, then, that the smaller the particle size the more thorough the heat and moisture can penetrate to the core of the particle in a given amount of time. Conversely, if we use a coarse particle in the mash, the heat and moisture will not fully penetrate the particle, leaving a hard, dry particle core that will not be soft enough for ideal pellet formation.

It is well known that as the average particle size of the mash is reduced, the surface area of the mash is increased geometrically. This concept is important because it is the surface on which the steam condenses, and it stands to reason that if we have more surface area, we can condense more steam per unit of mash weight.

The major reasons that pellet quality is often improved with fine grinding are directly related to particle size (heat/moisture migration) and surface area (steam condensation). If atmospheric conditioning is to be optimized, then we should be using the finest practical grind that we can.

Retention time

As previously mentioned, most of our ingredients have high insulating values; therefore, it takes time for the heat and moisture to penetrate into the core of each particle. The time available is limited to the time it takes for a given particle to move through the conditioning chamber. This is referred to as "retention time."

Retention time is not easily or precisely measured and, in reality, represents an average amount of time spent in the chamber. It can be crudely estimated by simply turning off the feeder and starting a stop watch at the same time. When the load on the pellet mill begins to drop, read the watch. This will give some idea as to the average retention time in the chamber. Other techniques involve injecting dye into the feed throat of the conditioner and collecting samples of the conditioner every two seconds. The visual color intensity will increase then decrease with progressive samples. The time at which you see the most intense color is taken as the average retention time. Similar results can be obtained using dyed iron tracers.

A more precise retention time can be determined if the pellet mill is equipped with a "dump chute" and a way to collect the output of the chute, and if the hourly pellet production rate is accurately known. At the beginning of the study, the mash feeder is cut off and the dump chute is activated. The conditioned mash is collected until no further mash leaves the conditioner. The conditioned mash is then weighed and the retention time can be calculated as in the following example:

Pellet throughput rate = 20 tons/hr (302 kg/minute)
Conditioned mash weight= 100 kg
100 kg ÷ 302 kg/min = 0.33 min avg. retention time
or 60 × 0.33 minute = 19.8 seconds

The objective of such an estimation is to optimize retention time and improve the overall conditioning process. In order to do so, one has to know where the starting point is. This brings up the question as to what the ideal retention time actually is. The topic has never been fully addressed, but most research would suggest that both pellet quality and throughput are improved if conditioning time is in the range of 30 to 90 seconds. It is not uncommon for a conditioner to fall short of these values, and there are real opportunities to improve pellet quality and throughput if appropriate changes are made. You must know where you are before changes are made in order to determine if the changes are positive or negative.

Possible options to increase retention time

Rate of mash passing through conditioning is controlled by both pick angle and shaft speed. Both can be adjusted to optimize retention time.

As a rule, original equipment manufactured (OEM) conditioners are factory set at a 30-45° forward angle. In other words, as the shaft rotates, all picks move the mash toward the discharge. The pick angle can be reduced to a more neutral position (75-85°) if the shaft speed is high (> 150 RPM). In other words, the pick angle can be set to a position nearly perpendicular with the shaft. This has the effect of reducing the "pumping" action of each pick, thereby increasing retention time.

In slow speed conditioners (80-120 RPM), the picks can be set more parallel with the shaft (at a 0-15° angle to the shaft). This setting will allow the picks to lift the mash and carry it part way around the barrel.

Setting the pick angle is a "trial and error" exercise at best. A word of caution—the pick angles at the feed throat should be retained at their factory setting for about the first 25% of the conditioner. This will ensure that the mash is moved rapidly forward into the conditioner and provides a void area for the steam to enter the chamber. Pick angle adjustment should be done in about the middle 50% of the conditioner length. As a suggestion, pick settings should be such that the mash level in the conditioner is about 70% of the available volume. If the conditioner is overfilled, there is the risk of choking the feeder and creating mechanical damage. Additionally, the operator needs to realize that increasing the retention time of the mash will increase the load on the conditioner drive motor, which may result in overload. Checking the current draw of the motor under load before adjustments are made will clarify the situation.

The second variable that can be optimized is shaft speed. Before addressing shaft speed, a discussion of the two prevailing philosophies is in order. Some engineers subscribe to something called "stirred bed" conditioning, while others follow a "fluidized bed" conditioning idea. The basic difference is the speed at which the shaft turns. A high shaft speed (fluidized bed) results in the mash being lifted and aerated as it moves down the barrel. The idea is to force mash particles to the top of the conditioning chamber where free or excess steam tends to lay. By placing mash particles in the free steam, it follows that more steam will be condensed onto the feed.

A slow shaft speed (stirred bed) allows the mash to settle to the bottom of the conditioner and be "gently" pushed along the barrel. This obviously allows for longer retention time, but leaves the upper part of the barrel open for steam to move freely without being utilized.

The critical part of the design of a conditioner is to provide for the introduction of the steam so that it is in close and immediate contact with the cooler mash so that instant condensation occurs. This often requires multiple steam entry ports or an elongated slit in the shell of the conditioner. Regardless of how it is done, the openings must be kept clear so that the steam velocity at the entrance is low and the steam is not forced through the mash too quickly. As far as adjusting shaft speed is concerned, there are no particular rules except that the speed should be great enough to provide good agitation and movement through the conditioner.

Shaft speed can be modified by changing belts and pulleys or by installing a variable frequency drive (VFD) controller on the drive motor. Since the probability of getting the shaft speed just right in one try is likely near zero, a VFD—if available—is the best choice. It may also turn out that different feeds require different shaft speeds or that seasonal ingredient changes (e.g., new crop grain) may do the same. In a plant with more than one pellet mill, a VFD could be installed on a single pellet mill to determine optimum speed and the other pellet mill may be set up with fixed drives at that speed.

In any event, it should be recognized that both pick angle and shaft speed are interrelated and are not independent. An additional word of caution is needed when increasing mash retention time. As dwell time is increased, the response time to changes in pelleting parameters is also increased. For example, if current dwell time is 10 seconds, an increase in feed rate should be noted on the drive motor in 12-15 seconds. If dwell time is increased to 30 seconds, a feeder rate change won't be noted until 35 or so seconds later.

In an effort to prevent steam from escaping contact with the mash in the conditioner, some suppliers are placing plates in the top of the conditioner just downstream of the feed inlet and upstream of the discharge. The steam is essentially trapped in the top of the conditioner until it condenses and mixes with the mash.

The conditioning process is, without doubt, the most important component of any feed pelleting system, at least as far as pellet quality is concerned. It is also perhaps the least understood component by pellet mill operators, most plant managers and even equipment suppliers. It was the purpose of this chapter to provide insight into some of the less-understood aspects of atmospheric conditioning and to point out some of the strong points and weak points of each option available.

There is no single conditioning option that is best for all applications and situations. In most cases, replacement is not an option; therefore, steps taken to optimize a given installation will result in the best pellet quality at the best production rate possible. It must be remembered, however, that all factors involved in pellet quality are inter-related and must ultimately be addressed if the process is to be successful.

Dr. Keith Behnke is a Professor Emeritus in Feed Science at Kansas State University.

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