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DINAPELL PELLET BINDER

Pellet quality improvements can be made for pelleted shrimp feed In conjunction with the use of an efficacious low inclusion, low cost pellet binder like Dinapell. See at http://www.dinatec.com/dinapell.htm.

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Introduction

Pelleting shrimp feed costs a lot of money, and better pellets cost a little more. Payback comes in the form of convenience in handling the feed and more efficient use of the feed by the animal. Improved efficiency is due in part to heat processing which reduces pathogens and makes starches more digestible. A significant portion of the improvement is related to the physical form of the pellet. Durable pellets reduce waste, reduce segregation, improve palatability, and allow larger meals to be eaten in less time. All these factors contribute to optimized feed efficiency.

This paper will review experiments that have been performed in the U.S. which quantify the benefit of pellet quality in various species. In addition, methods of monitoring pellet quality will be reviewed and compared.

Effect of Pellet Quality on shrimp Performance

It is generally recognized that good pellet quality improves the feeding efficiency, growth, and uniformity. Shrimp are slow bottom eaters and therefore pellets must also have good water stability.

Measuring Pellet Quality

Pellet quality does have economic importance; it should not be left to chance. Fines are generally formed by mechanical action on the pellets during transport. These forces may be classified as impact, compression, and shear. Impact shatters the pellet surface and any natural cleavage planes in the pellet; compression forces crush the pellet; shear forces cause abrasion of the edges and surface of the pellet. A discussion of test methods that measure the combined effects of these forces follows.

Kansas State Method

In an effort to study pellet quality Kansas State University (Pfost, 1962) built a model handling systems consisting of a bucket elevator, a hopper, and a screw conveyor. Fifty pounds of pellets were continuously cycled through this system for 10 minutes. At the end of the test, fines would be screened off from the pellets and the percentage of pellets surviving would be calculated as the Pellet Durability Index (PDI). This test was used as an absolute measure of durability to compare against other model test methods, notably the Stoke's hardness test and the tumbling can method.

Correlation with the tumbling can was excellent (.949) and it was officially adopted as a standard method by the American Society of Agricultural Engineers.

In field trials LignoTech compared the level of fines predicted by the KSU Tumbler to actual fines in the feed as it was removed from the farm silo. The relative differences in quality were correctly predicted. The actual level of fines was also very similar to the predicted level. See Figure 1.

The KSU Tumbler has a few short-comings that has led to modification or development of completely new testers. The tumbler was developed using pellets that were primarily corn/soya in make up. When used to evaluate dairy pellets of high durability (PDI>96) the standard test is not abrasive enough to discriminate levels of quality. One simple option to correct this is to add two 3/4" hex steel nuts to the chambers. These provide additional compressive force as they impact against the pellets.

Figures 2a-2c illustrate the ability of three different test methods to measure the affect of temperature change on high-midds dairy pellets. The standard KSU test shows no discrimination at all. When nuts are added to the tester there is some indication that pellet quality improves with increasing temperature. Pellet hardness results seem to be completely random.

Direct Measure of Fines

Measuring fines off the cooler, or from grab or probe samples in storage or transport is unreliable. Fines definitely segregate as the feed is moved (Figure 3). If a single sample is taken the result may be completely misleading. When multiple samples are taken it is possible to calculate an average and a standard deviation.

Measuring fines directly off the die can provide an indication of pellet quality for poultry and turkey feeds (Figure 4). Care should be taken to collect from the same position (quality from the front of the die may be different than the back) and that excess pellets are not allowed to roll off the collection vessel. Of course this method is of little help if there is leakage of meal around the die.

Holmen Pellet Tester

Another shortcoming of the KSU tester is the time required to complete a test. The Holmen Tester, developed in England, provides a level of speed and convenience that is appreciated by those who do durability tests on a regular basis. The Holmen Tester circulates pellets through an air conveyance system for 30 seconds (or up to 2 minutes if needed). Pellets are subjected to both impact and shear in this method that simulates pneumatic rather than mechanical conveyance. Correlation between the Holmen Tester and the KSU Tester is excellent (Figure 5); both are good tools for measuring pellet quality.

Open Screen Tumbler

A variation of the KSU Tumbler replaces the solid cover with a screen which allows fines to exit the compartment during tumbling. The tumbler is surrounded by a case which catches the fines and funnels them down to a tray. In this system it would be possible to weigh the fines and calculate PDI, however, the typical procedure used is to measure the volume of fines. This has some merit

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as it is simple and it relates directly to what the customer will see upon visual inspection. This method is used by only a few companies.

Tube Tester

The KSU and Holmen Testers offer two types of commercially manufactured machines that have become standards of the industry due to their excellent performance. In spite of these two options, a continuous variety of home-built pellet testers are still found. Of these, the simplest and most effective is the tube tester (Figure 6). It is simply a length of pipe that is rotated end-over-end at a rate which allows the pellets to fall the length of the pipe when it reaches the near-vertical position. Generally the sample size is 100 g of pellets and steel nuts are added to increase pellet degradation. The major force acting on the pellets in this test is shear. Compression and impact will also occur as the pellets and steel nuts strike the end of the pipe. Pipe length varies between 50 and 100 cm.

Longer pipes require greater diameter and slower revolution speed. Multiple pipes may be fitted on the same axis. The test period may vary between 5 and 20 minutes. This is an effective test but it is not an industry standard. Specifications would need to be developed in-house.

Pellet Length

Pellet length is a simple way to monitor quality. When samples are collected at the same sampling point, longer pellets indicate greater durability and less fines (Figure 5). When collected at multiple sampling points pellet length can indicate points of destruction in the handling system.

Determining the average length of pellet is not a reasonable procedure. What is actually done is to measure the number of pellets in a weighed sample of feed and calculate the number of pellets per gram. A 10-20 g sample of screened pellets is usually sufficient.

Hardness

Correlation between the KSU pilot plant results and the Stoke's hardness test was not as good as with the tumbling can (.784 vs .949). This could be due to the fact that the Stoke's test measures only compression and ignores impact and shear while destruction in the model handling system was caused primarily by shear and secondarily by impact. The real problem with the Stoke's test is the sample size, the operator must select individual pellets to be tested. It is normal to reject an obviously weak pellet, and by doing so, result are biased. In contrast, the tumbling can method uses a 500 g sample which includes both good and bad quality pellets.

Figure 2c illustrates hardness results at different temperatures. Temperature is believed to affect quality but hardness results appear to be random. In another trial hardness had a negative correlation to durability (Figure 7). This is rare but it can occur. It appeared that molasses was added at variable levels during the pelleting run. Addition of molasses can make the pellet soft and gummy; it may even be possible to bend the pellet. Soft pellets can be very durable, making the hardness test an inappropriate method of measuring quality.

Summary

Whenever feed is too expensive to waste, pellet quality begins to have an economic value. Expect your customers to give the quality of your pelleted feed at least a subjective measurement. There are a number of good ways that can be used to objectively measure and record the quality of pellets during the manufacture process. Objective measurement and recording is the first step toward correcting destructive conditions and improving quality. It may also allow opportunity for cost savings when quality is found to be above standard specification.

As a general guideline one should consider a boiler capacity of 5 HP for every ton of feed per hour produced. It is imperative that a specific individual be made responsible and accountable for the complete steam generation system including the boiler. This individual will have overall responsibility and accountability for monitoring and generating all the system check points required below. The information generated to be discussed weekly with head of QC and plant management.

The factors that influence pellet quality can be divided into several categories. It is generally agreed that the formulation is, by far, the most important factor affecting pellet quality. The cereal grain used (corn vs. wheat) and its percentage can have great influence. The inclusion of fats or oils (above 1%), regardless of the source, can dramatically reduce pellet quality.

Fineness of grind can have a great deal of influence on pellet quality. As a rule the finer the grind, either pre- or post-grind, the better the pellet quality. Particle size affects both the extent of conditioning and the way in which particle bonding occurs in the pellet itself.

In terms of pellet mill operations, the conditioning process has greater influence on pellet quality than does die specification. A great deal of attention must be paid to steam quantity and control, moisture content, retention time and mixing action within the conditioner. In general, most feed manufacturers have not optimized the conditioning process but try to solve pellet quality issues using a thicker die. While this often results in improved quality, we often see an unacceptable drop in production rate.

Developing a full understanding of pellet quality and the factors that influence it is still fertile ground for research and idea development. As new ingredients become available and equipment and technological advances occur, a thorough understanding of factors affecting pellet quality will be mandatory.

LITERATURE REVIEW

Pelleting was introduced into Europe about 1920 and into the U.S. feed industry in the late 1920's (Schoeff, 1994). Its popularity has grown steadily until about 80% of all feed in the U.S. are currently pelleted. Today, the process is widely used because of both the physical and the nutritional benefits it provides. The physical benefits include improved ease of handling, reduced ingredient segregation, less feed wastage, and increased bulk density. Nutritional benefits have been measured through animal feeding trials (Falk, 1985).

EFFECT OF FEED FORM (MEAL VS PELLETS) ON ANIMAL PERFORMANCE

As a rule, feeding pelleted feed improves animal performance and feed conversion compared with feeding a meal form of a diet. The improvements in performance have been attributed to (Behnke, 1994):

1. Decreased feed wastage
2. Reduced selective feeding
3. Decreased ingredient segregation
4. Less time and energy expended for prehension
5. Destruction of pathogenic organisms
6. Thermal modification of starch and protein
7. Improved palatability

Research has concentrated primarily on the benefits of feeding pellets versus meal. Pellet quality has become more important in the swine and poultry industries as integrators continue to expand and recognize the value of feeding quality pellets.

THEORETICAL AND PRACTICAL ASPECTS OF PELLET QUALITY

ADHESION

Adhesion is the process by which materials are held together by a physical to chemical interaction of the material. This is accomplished by joining the surfaces of the material by melting the materials together or by applying an adhesive between them. An adhesive is defined as a material which, when applied to surfaces, can join them together and resist separation (Wake, 1976). Dinapell is a synthetic adhesive and NatutaPell is a natural adhesive and although it should be obvious that in pelleting, the approach used is seldom to "apply" an adhesive, both Dinapell as a synthgetic adhesive and Naturapell as a 100% natural adhesive work exceptionally well. The normal approach taken by most feed millers is however, to try, through temperature and moisture control, to activate the natural adhesives that are typically found in the feed ingredients. The latter is not nearly as effective as the use of pellet binders like Dinapell and Naturapelll.

ADHESION THEORIES

Several theories on the mechanism of adhesion at the interface between particles have been proposed. The theories with application in the pelleting process include:

1. Mechanical Interlocking
2. Diffusion
3. Adsorption

Kinlock (1987) described the basic concepts of each theory and the mechanisms by which adhesion occurs:

> ***Mechanical Interlocking*** is based on the fact that adhesives flow into rough surfaces, become rigid, and hold the materials together. The theory also suggests that rough surfaces will improve the contact area and thus improve bond strength.
>
> ***Diffusion* theory** is based on the diffusion of polymers at the interface between material surfaces. Diffusion occurs when materials are heated and allowed to diffuse across the interface between materials. This phenomenon can occur only when the temperature of the polymer is above the glass transition temperature of the polymer.

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***Adsorption* adhesion** occurs due to interatomic and intermolecular forces established between atoms and/or molecules at the surface of the adhesive and the substrate. The attractive forces are ionic, covalent, hydrogen bonding dipole interactions, and Van der Waal forces. The bond energies of the forces and effective ranges have been summarized by Allen (1990).

RHEOLOGICAL CHARACTERISTICS OF FEED INGREDIENTS

The rheological and functional characteristics of feed ingredients vary depending on their physical structure (crystalline vs amorphous) and chemical composition. Materials that are heated go through either a first or second order glass transition or a combination of first and second order transitions. First order transitions involve the melting of crystals, whereas second order transitions are a relaxation of polymers. Crystalline materials (e.g. sugar) go only through a first order transition. Partially crystalline materials (e.g. starch) go through a second order transition prior to the first order transition. Amorphous materials (e.g. cellulose, lignin) exhibit only a second order transition.

The temperature at which the amorphous regions of a polymer begin to relax or become mobile is defined as the glass transition temperature. Glass transition temperatures have been reported for starch (Zeleznak and Hoseney, 1987); wheat gluten (Slade, 1984; Hoseney et al., 1986), and for corn gluten (Lawton, 1992). Glass transition temperature is inversely related to moisture content. As the moisture in the system is increased, the temperature at which the material becomes mobile decreases. Feed ingredients have glass transition temperatures below the temperatures normally associated with the conditioning process (70-90 C) when the moisture content is between 15 and 18%. This suggests that feed ingredients begin to flow during the conditioning and pelleting process, and the amount and location of material flow depends on the temperature and location of the water (surface or intra-particle).

The level of total pellet starch gelatinization and starch damage has been reported to be negatively correlated with pellet quality (Stevens, 1987; Lopez, 1993). Starch damage was found to be greater at the outer surface of the pellet at lower conditioning temperatures. However, starch damage decreased as the conditioning temperature increased, indicating that the damage was primarily due to mechanical shear between the die surface and the starch and not due to hydrothermal elevation alone.

Woods (1987) examined the functional role of starch and protein in the pelleting process. The addition of raw soybean flakes increased pellet quality as compared to heat treated denatured soybean meal. In additional, pre-gelatinized starch improved pellet quality compared to native starch. He concluded that protein had a greater influence on pellet quality than did the starch. This finding has been recently confirmed by Briggs et al. (1999).

The data suggests that the level of starch gelatinization may not be as important as the location of the gelatinized starch. It is apparent that the gelatinization at the surface of the feed particles is critical to the formation of intra-particle bonds necessary for the formation of strong, durable pellets. Starch gelatinization at the particle interface in conjunction with protein plasticization would result in polymer diffusion between starch granules and protein molecules, resulting in adhesion to the particles.

EFFECT OF FORMULATION ON PELLET QUALITY

Least-cost formulation is designed to meet the nutritional parameters required by the target animal. However, the effect of formulation on processing, specifically pelleting, is seldom considered by most nutritionists.

Ingredients currently used by the feed industry have been used as adhesives for over 100 years. By-products from food and meat processing industries have been used as adhesives in the plywood industry over the last century (Detlefsen, 1989). Casein obtained from skim milk by acid denaturation of the protein is used in wooden doors. Casein is present in whey and skim milk used in swine diets. In addition, blood from slaughter plants has been used as an adhesive in bonding layers in plywood. Dried blood and blood plasma are also used extensively in swine diets. Starch, cellulose and collagen have been used in the production of industrial packing materials and the application of labels (Lazarus, 1990).

The addition of fat to the mash pre-pellet usually results in decreased pellet quality (Richardson and Day, 1976; Headly and Kershner, 1968). However, the addition of protein and fiberous materials increase pellet quality. Fahrenholz (1989) reported an increase in the pellet durability of swine diet pellets and the level of wheat middlings increased from 0 to 45%. McKee (1988) increased pellet quality and water stability of catfish diets by increasing the level of wheat gluten from 0% to 10%. Lopez (1993) also reported the addition of vital wheat gluten resulted in a positive affect on pellet quality and water stability, but the addition of cassava meal had a negative effect. Lawton (1989) reported a linear increase in tensile strength as the amount of protein in a tablet increased at the expense of starch.

EFFECT OF PARTICLE SIZE ON PELLET QUALITY

Decreasing the particle size of ingredients results in a greater surface area to volume ratio. Smaller particles will have a greater number of contact points within a pellet matrix as compared to larger particles. Anand (1970) demonstrated contact points between polystyrene beads increased 3 to 4 to 7 as bead size decreased to allow 3, 4, or 7 particles per unit area, respectively. Penetration of heat and moisture to the core of a particle can be achieved in a shorter amount of time with small particles and a large surface area per unit of weight.
Stevens (1987) reported no difference in pellet quality when the mean particle size of corn and wheat was reduced from 1023 to 551 microns (u) and from 802 to 365 u, respectively. Martin (1983) reported similar results using corn and grain sorghum. However, Wondra et al (1995) reported an increase in pellet durability as particle size was reduced from 1000 to 400 u. The aquaculture feed industry will typical grind ingredients to less the 250 u for greater pellet water stability. The combination of small particle size and long term, high temperature conditioning produces pellets that have the greatest water stability.

CONDITIONING

The importance of steam conditioning was quantified by Skoch et al (1981) in an experiment comparing dry pelleting with pelleting using steam conditioning. The results of this study indicated that steam conditioning improved pellet durability and production rates and decreased the amount of fines generated and energy consumption. From this, it was concluded that steam acted as a lubricant to reduce friction during pelleting.

Mash entering the conditioner may be comprised of a wide variety of ingredients that make up the diet formulation. The nutritional, as well as physical. properties of this mash have an effect on conditioning and eventual pellet quality. According to Reimer (1992), pellet quality is proportionally dependent on the following factors: 40% diet formulation, 20% particle size, 20% conditioning, 15% die specifications, and 5% cooling and drying. If this is correct, 60% of pellet quality is determined before the mash enters the conditioner. This increases to 80% after conditioning, but before mash has even entered the die chamber of a pellet mill.

There has been some research conducted looking at the effects of the first two of these variables, diet formulation and particle size, on pellet quality. Studies by Stevens (1987) and Winowiski (1998) have compared the pellet durability of diets containing corn with those where some or all of the corn was replaced with wheat. In both instances, pellet durability was higher for the diets containing wheat. It can be reasoned that this is due to the higher crude protein content of wheat (13%) as compared to corn (9%). This finding is in agreement with a study conducted by Briggs et al. (1999) which found that increasing the protein content in a poultry diet from 16.3% to 21% increased the average pellet durability from 75.8 to 88.8%.

Particle size is the second factor that Reimer (1992) proposed would dictate about 20% of pellet quality. Decreasing particle size from a coarse to a fine grind exposes more surface area per unit volume for absorption of condensing steam and increases the surface area available for bonding. MacBain (1966) indicated that a variation in particle size produces a better pellet than a homogeneous particle size. Work by Stevens (1987) when pelleting corn or wheat based diets, however, found that particle size had no effect on pellet durability index (PDI) as determined by the tumbling can method.

MASH MOISTURE

Some familiar with feed technology may argue that the moisture of mash entering the conditioner should fall into the category of diet formulation. Water may be physically removed or added to ingredients or formulations in a diet in order to alter moisture content. There are, however, two types of moisture: bound moisture and added moisture (MacBain, 1966 and Leaver, 1988). Bound moisture is that which is chemically or physically bound to ingredient components and is not easily removed. Added moisture is that which is added at the conditioner or mixer and serves to soften feed particles and lubricate the mash as it moves through the die.

The initial moisture of mash entering the conditioner is thought to dictate the amount of steam that can be added to the mash. Leaver (1988) indicates that, typically, no more than 6% moisture can be added at the conditioner. Thus, large variations in initial mash moisture will be reflected in the moisture of hot mash. This may cause varying pellet mill performance if the characteristics of steam added to the mash are not adjusted as the moisture changes. Experiments recently conducted at Kansas State University have compared the effects of mash moisture contents between 12% and 15% on pellet quality. The results of this experiment show that there is a high correlation between cold mash moisture and PDI (Greer and Fairchild, 1999). Adjustment of mash moisture to 14% produced the highest quality pellet with the most efficient pellet mill operating conditions (Muirhead, 1999).

RETENTION TIME AND CONDITIONER DESIGN

Retention time refers to the amount of time that mash feed spends in the conditioner. Thus, it is a measurement of the duration of exposure mash has to steam for heat and moisture absorption. A conditioner operates as a continuous system in which mash is constantly entering and exiting. Flow through a conditioner, however, cannot be characterized as simple plug-flow since the mash experiences some axial and longitudinal mixing as well. Therefore, retention time may better be characterized as a residence time distribution (RTD) function (van Zuilichem et al., 1997). This is a mathematical relationship describing the dwell time of components within the conditioner with respect to time (van Zuilichem et al, abid).

Retention time is affected by conditioner design including physical dimensions and operating parameters. The design and dimensions of conditioners vary in diameter, length, type of picks, number and placement of picks, pick angles, steam inlet location, presence or absence of baffles, and baffle placement. Changing any of these physical parameters will affect conditioner retention time.

Within an existing conditioner, the most common ways to manipulate retention time are by adjusting pick angles or changing shaft speed. Adjusting pick angles changes the forward motion and tossing of product as it is conveyed through the conditioner. This angle adjustment, however, can be time consuming as the conditioner must be powered down and locked out before the operator can access the picks inside of the conditioner. In addition, the pick angle is not easily measured, and the location in relation to the shaft is, at best, an estimate. Increasing or decreasing shaft speed as a means of manipulating retention time requires that there be a variable speed drive on the conditioner. In addition to slowing down the conditioner RPM, this adjustment will affect the amount of tossing motion that a product undergoes as it passes through the conditioner.

Briggs et al. (1999) used the first of these methods, pick angle adjustment, to examine the effect of retention time on pellet quality. One conditioner was used in the experiment and the angles of the picks were changed to give two different retention times. A standard setting was used in which all mixing picks were set at about a 45 forward angle. The second setting was a parallel pitch where all picks were set parallel to the conditioner shaft, except for the first and last. Average retention time was estimated at five seconds for the standard pitch and fifteen seconds for the parallel pitch design.

The results of this study indicated that degree of pitch, or conditioner design, affected pellet quality. Pellet durability of mash conditioned using the parallel pitch averaged 5 points higher than pellets produced with the standard pitch. This improved durability can be explained by the longer retention time achieved with the parallel pitch. Conditioner design and retention time remains an area where additional research is needed so that benefits of different designs, dimensions, and operating parameters can be understood and used to the feed manufacturer’s benefit.

STEAM PROPERTIES

High levels of heat and moisture are needed to achieve proper pelleting of grain-based diets that are high in starch (MacBain, 1966). Because of its unique thermodynamic properties that allow for the transfer of heat and moisture simultaneously, steam conditioning has presented itself as one of the most important factors in pelleting.

According to Reimer and Beggs (1993), the purpose of heat in conditioning is to gelatinize the starch portion of the feed. Other benefits of heat are to destroy pathogens and other microorganisms, and to promote drying of pellets in the cooler. Smallman (1996) explains that the moisture contribution from steam forms a cohesive bridge between particles and has a profound effect on pelleting. This moisture soaks into materials to soften them, and has been found to act as a lubricant to reduce friction between the mash and the walls of the die (Skoch et al., 1981). To optimize the conditioning process, the proper balance of heat and moisture must be obtained. Steam has the ability to provide this combination, however, it exhibits a wide variety of properties that must be understood and correctly utilized to produce high quality pellets.

Steam may exist in three different conditions: saturated, superheated, or subcooled. The American Society of Mechanical Engineers has published steam tables (ASME, 1967) that list the thermophysical properties of steam for each of these conditions. These tables include the relationship between pressure, temperature, specific volume, enthalpy, and entropy. For saturated steam, the relationship between temperature and pressure is unique. If pressure is held constant, adding heat above the saturation temperature will produce superheated steam. Likewise, at a constant pressure, cooling steam below the saturation temperature creates subcooled steam. "Under superheated or subcooled conditions, fluid properties, such as enthalpy, entropy and volume per unit mass, are unique functions of temperature and pressure. However, at saturated conditions, where mixtures of steam and water coexist, the situation is more complex and requires an additional parameter for definition" (Stultz and Kitto, 1992).

The "additional parameter" referred to here is steam quality, or the percentage of steam that is in the vapor phase. Steam quality is calculated as the mass of steam divided by the mass of steam and water (Stultz and Kitto, 1992). Multiplying this by 100 gives the percent steam quality. As steam is transferred from the boiler to its location of use, it will lose some energy. Therefore, final steam quality at the conditioner depends upon "energy put into the steam at the boiler, heat losses, and water addition or removal in the steam system" (Reimer and Beggs, 1993). Steam characteristics, along with the steam quality and flow, dictate the amount of heat and moisture that is added to mash at the conditioner.

There has been a lot of discussion concerning the use of high pressure versus low pressure steam for conditioning. The thermodynamic properties of low (138 KPa or 20 psig) and high (552 KPa or 80 psig) pressure steam are compared in the following table:

Properties of Saturated Steam

Pressure	138 kPa, (20 psig)	552 kPa, (80 psig)

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Temperature	126 C, (259 F)	162 C, (324 F)
Specific Volume	.75 m^3/kg, (11.9 ft^3/lb)	.29 m^3/kg, (4.67 ft^3/lb)
Sensible Heat, h_f	529.3 kJ/kg, (227 BTU/lb)	684.3 kJ/kg, (294 BTU/lb)
Latent Heat, h_{fg}	2185.4 kJ/kg, (939 BTU/lb)	2075.96 kJ/kg, (881 BTU/lb)
Total Heat, h_g	2714.7 kJ/kg, (1166 BTU/lb)	2760.3 kJ/kg, (1185 BTU/lb)

The temperature of 552 kPa steam is 36 C (65 F) higher than the temperature of 138 kPa steam. Regardless of the steam pressure in the line, in an atmospheric conditioner, condensation and heat transfer only occurs at atmospheric pressure. This means that the temperature of steam in the conditioner must first be reduced to around 100 C before any condensation including moisture and heat transfer occurs.

The specific volumes of 138 and 552 kPa steam are also quite different. To provide similar quantities of these steams, a larger diameter pipe is necessary for low pressure steam because of its increased volume. This explains why steam is often transferred from the boiler to its location of use at a high pressure and then regulated down to a lower pressure.

Enthalpy refers to the heat or energy that steam has available in kJ/kg. This energy is broken down in the steam table as sensible heat, latent heat, and total heat. Sensible heat is the energy required to heat one kilogram of water from 0 C to the boiling point at the corresponding temperature and pressure. Latent heat, or heat of vaporization, is the energy needed to convert this kilogram of boiling water into one kilogram of steam. Table 1 shows that there is less than a 2% difference in the total energy of the high and low pressure steam.

Though the thermodynamic properties of saturated steam at a given temperature and pressure are known, the debate still continues as to what pressure gives the best pellet quality and mill performance. MacBain (1966) presents data to show that low pressure steam produces a higher quality pellet with greater capacity on high-starch formulations. This is in contrast to Leaver (1988) who states that the use of high pressure steam is more advantageous than the use of low pressure steam. Yet others, such as Thomson (1968), believe that the total energy of high and low pressure steam are similar enough that it does not make much difference as to which is used.

Stevens (1987) completed a study comparing the use of steam at 138 and 552 kPa (20 and 80 psig) to condition mash to 65 C (149 F). A swine diet consisting of primarily 72.4% corn or wheat was used in the study. Results indicated no significant differences in production rate, mill efficiency, pellet quality, percent fines, or moisture addition at the conditioner for the two diets at these pressures. Research by Briggs et al. (1999) agreed with these results in a study also comparing the effects of 138 and 552 kPa (20 and 80 psig) steam on poultry diets.

A review of the literature indicates a general agreement that high quality steam is necessary for efficiently producing a durable pellet (MacBain, 1966; Skoch et al., 1981; Stark, 1990; Maier and Gardecki, 1993). Despite this, there is no published data examining the effects of steam quality on pellet durability or pellet production. Wet steam, or that which has a quality less than 100%, is known to contain less energy then saturated steam. Therefore, using wet steam requires a larger quantity be added to reach a target conditioning temperature. Taking this a step further, it can be reasoned that moisture addition to the mash should increase as steam quality decreases. "Steam quality directly affects the maximum obtainable feed temperature because of moisture limits" (Reimer and Beggs, 1993). If the pellet mill reaches a choke point before the conditioning temperature is obtained, adjustments must be made. This is an area where additional research is needed.

SUMMARY

After reviewing the body of published scientific literature as well as reports from field studies and skilled practitioners of pelleting, it is easy to conclude that there is still a great deal of art in the science of pelleting. There is truly a great deal that we don't understand or, perhaps, that we misunderstand about pelleting. Reimer (1992) indicated that the factors that affect pellet quality can be identified as: formulation, particle size, conditioning, die specification, and cooling and drying. If his hypothesis is true, these allocations provide a useful roadmap to solving many of the quality problems associated with pelleting.

If we assume that formulation and particle size are relatively constant, the next significant factor is conditioning. While a good deal has been done in the way of research there is still a great deal of misunderstanding concerning the design, configuration, and operation of these devices.

Managing steam quality and control in a pelleting operation is critical to success. In many instances, items as simple as proper sizing of pipes and valves and adequate insulation have been overlooked and have caused quality problems.

While die selection was not directly discussed in the manuscript, it should be noted that this factor has significant impact on both pellet quality and system productivity. A thicker than needed die can result in good quality pellets but less than acceptable production rates. An overly thin die will often result in poor quality pellets but excellent throughput. It is often necessary to have several dies of the same bore diameter but different effective thickness in order to optimize both pellet quality and production.

It should be recognized that pelleting is still fertile ground for research and new developments. As new technology and new ingredients become available, changes will have to be made to optimize pelleting operations.

Specific steps you can take to maximize and improve financial returns through the use of a pellet binder called Dinapell.

The PSIG setting for the boiler should be set to a level reflecting 90% of the total PSIG rating for the boiler. The safety valves must be closely monitored to see if they will support this level for normal operation. This higher PSIG setting will increase the saturated steam temperature and steam volume. Once this is accomplished at the boiler level the regulator pressure can be increased so that the steam released into the mash will be hotter. This will in turn help to elevate the mash temperature more closely to the desired level of 90 degrees centigrade minimum.

Blowdown should be approximately 5 % of the hourly boiler capacity. Both bottom blowdown and top blowdown parameters must be followed according to the boiler manufacturers operations manual. Improper or insufficient blowdown will affect the boilers capability to transfer heat from the boiler tubes to the water. This happens in two ways. First by the accumulation of scaled material in the outer walls of the fire tubes which insulates them and precludes adequate heat transfer from occurring to heat the water into steam. This is due to increased levels of TDS when there is insufficient blowdown. Not knowing what the TDS levels are does not help this situation. Normally for boilers of average size TDS levels should not exceed 1500-3500 PPM. The indicated TDS levels can be maintained by doing a continuous surface blowdown in some instances. Please check manufacturers recommendations in order to do this. Generally speaking the lower the levels of TDS the better the steam quality will be.

The second condition is affected indirectly as a result of the boiler having to work harder and depending on the burners' fuel efficiency, soot material can begin to build up inside the fire tubes adding additional insulation to the inside of the tube walls. This tends to exacerbate the problem related to heat transfer.

Determine current boiler capacity as it relates to sustainable production volume. (Guideline is 5 BHP per metric ton/hr)

A complete maintenance and clean up of the boiler system is recommended. This to include removal of any scaling material on the exterior walls of the fire tubes and any soot in the interior walls. The burner to be calibrated for efficient combustion to minimize soot build up and maximum fuel usage efficiency.

Initiate continuos surface boiler blowdown. Check manufacturers guidelines for your particular boiler make and model. A heat exchanger may be a consideration when continuos surface blowdown is initiated in order to recuperate some of the energy lost.

Bottom blowdown is to be performed and monitored at least 2 times a day initially. This frequency to be monitored and adjusted up or downwards as needed. Water level should not drop more 5% of the total hourly water capacity for the boiler at stated rating.

Monitor TDS daily initially until a clear perspective of trend is established. Once this perspective is elucidated the frequency for this monitoring point may be adjusted downward as needed. Keep TDS at or below 1500 ppm.

A thermo coupling device should be installed at the exit of the boiler chimney stock if it is not already there. Temperature readings of the exhaust gases to be monitored initially every 2 hour.

This monitoring point will be intrinsically related to the operational PSIG setting for the boiler and will give us an indication of how effectively heat is being transferred from the fire tubes to the boiler water. The exhaust gases should be not more than 40-50 degrees above the temperature rating for the particular saturated steam pressure setting for the boiler. Example if the boiler operates between 90 to 120 PSIG, the saturated steam temperature for that pressure range is between 321 to 350 degrees Fahrenheit. Therefore the exhaust gas temperature should not be in a higher range than 371-400 degrees Fahrenheit. Exit boiler stock gas temperatures that are higher than the related range may mean that the boiler fire tubes have become insulated and are not working effectively. It becomes evident that the monitoring of the boiler PSIG level and the boiler stock exit gas temperature must be time related in order for this analysis to be valid.

The Steam Pipe System

Steam pipe design should allow a steam velocity of approximately 6000 feet per minute predicated upon the boiler size, possible PSIG settings, pipe diameter and amount of steam or volume.

Steam quality is measured in terms of its thermodynamic properties. These are temperature, pressure, enthalpy and entropy. Temperature is only one such property and is associated to a specific PSIG pressure setting. Please refer to steam temperature/ pressure charts to see equivalent temperatures for a given steam PSI level. Enthalpy is another thermodynamic property . It is defined as the total amount of energy available to raise the heat in the mash. Enthalpy is normally designated by the symbol H. It is a thermodynamic function of a system, equivalent to the sum of the internal energy of the system plus the product of its volume multiplied by the pressure exerted on it by its surroundings. Enthalpy may be expressed in BTU=s per pound for a given PSI setting. Entropy relates to a quantitative measure of the amount of thermal energy not available to do work for a closed thermodynamic system. It is designated by the *Symbol* S. Normally an industry wide acceptable level of entropy in any given steam line is not more than 7%. A steam regulator reduces steam pressure at a constant H.

Steam Regulators

The most common problems in the steam lines in pelleting mills are defective steam regulators, blocked steam nozzles and worn conditioner paddles. Pertaining to the defective regulators this category includes broken or malfunctioning units as well as fitting the wrong pipe size to the regulator and setting the regulator to the wrong PSIG setting. Of all plants evaluated in the USA these three items accounted for more than 60% of the problems. Although the latter is not normally associated with the steam line it does have much to do with mash retention time in the conditioner and therefore affects the amount of steam to which the mash can be exposed to. These items must be checked frequently to determine if they meet operational standards. Steam pipes that are leaking and not totally insulated do cause dramatic heat loss and PSIG drops. When insulation on the steam pipes is removed or is not sufficient this causes condensation to occur in the pipes.

A standard industry wide is for not more than a 7 % drop in the steam lines. To much of a PSIG drop combined with steam line leaks will result in significant temperature drops as well. For example a 20 PSIG drop from 120 to 100 implies lowering the temperature from 341.27 degrees Fahrenheit to 327.82 yielding an approximate 13.45 degree F drop. This is part of the reason why many feedmills are unable to get their conditioner temperature to our minimum required objective

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of 90 degrees centigrade, (195 Fahrenheit)

The regulator must be able to administer a constant steam pressure to the conditioner. Steam pressure variance supplied to the conditioner above 2 PSIG is unacceptable. The regulator must be monitored periodically to insure that it is able to conform to these specs. Too low a setting for the regilator will lower efficacy. Generally speaking the higher the PSIG setting, the higher the temperature will be. For a PSIG setting of 22 at the regulator level, the corresponding temperature is ~230 degrees F .

By increasing the regulator setting to for instance 45 PSIG, (this is only an example and not a final recommendation), we would be able to inject steam into the conditioner at a temperature of 274.44 degrees F. This will yield a gain of 44.44 degrees F. The additional energy thus gained will make a significant contribution towards resolving the problem related to achieving the targeted temperature of 195 degrees F.

A consideration here to take into account is that since the mash will be cooked at a higher temperature, the resulting pellet may vary in coloration from the previously undercooked mash. This will have to be explained in advance to the customer base in order to avoid complaints and needless uncertainty in the market place.

The regulator distance to the conditioner may also be shortened if possible to obtain better results. The shorter the distance, the less energy loss in the piping system from the regulator to the conditioner. This piping should also be well insulated. The goal here is to have the saturated steam condense uniformly over each particle in the mash and not in the piping system after the regulator drops the pressure. Particle size and uniformity of moisture in mash will be affected negatively by adding moisture in the form of liquid water to the conditioner. The reason for this is that as the water enters the conditioner it will not condense uniformly around each feed particle as should be the case with saturated steam, but rather it will have a tendency to form clumps of fed particles which in essence will have the same effect as having a dis-uniform particle size. Since the water will tend to clump around various feed particles the effect will be also to have non homogeneous moisture level in the mash.

Action Line

Objective; to be able to reach a minimum temperature of 90 degrees C, (195 degrees Fahrenheit) at the conditioner/pellet mill level.

Repair and if necessary overhaul steam line completely in order to stop steam leaks.

Re check steam pipe sizing design.

Completely insulate steam line piping using high efficiency insulating material.

If practical insulate conditioner.

Check steam trap location and functionality.

Monitor steam traps and record findings daily.

Do a complete initial checkup of the steam regulator to insure that it is functioning properly.

Set steam regulator pressure initially to at least 35 PSIG

Monitor steam regulator setting and record findings weekly.

Monitor and if needed re calibrate steam regulator monthly, Record findings.

Monitor PSIG indicator just before steam regulator initially every 2 hour and record.

Monitor PSIG setting for the regulator initially every 2 hour and record.

If practically possible relocate steam regulator as close as possible to the conditioner and insulate steam pipe from regulator to conditioner.

Perform an initial and thorough steam nozzle cleanup.

Monitor and clean steam injection nozzles as needed but not less than at the end of every shift. Record findings.

Monitor and record mash humidity and temperature coming into the conditioner every 2 hour initially

Monitor and record mash temperature and humidity exiting the conditioner to the pellet mill every 2 hour.

Once temperature target of 95 degrees C is achieved gelatinization of the starch fraction will begin to occur. In order to avoid production capacity losses the pellet mill operator can now use a thinner higher capacity pellet die in keeping with the amount of oils and fat added. This die thickness for the CPM pellet mill can range between 1 3/4 to 2 inches depending on the percentage of oil and fat inclusion rate. Generally speaking one does well to remember that the thicker the die the lower the choke point and the lower the production volume, *ceteris paribus* the opposite is true. Please consult your pellet mill technical support representative for further details on this subject.Texturizer
The texturizer is prior to the mixer and is set to between 350-373 microns. Vitamins are added in the mixer after the texturizer.

The more we learn regarding the making of a good shrimp pellet the more we realize the importance of having a very fine size and uniform particle. Dis-uniform and coarser than required particle size will have detrimental effects in pellet quality.

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We recommend that particle size be no larger than 200 microns. Vitamins can be added after the texturizer reduces particle size to not more than 200 microns to keep them from being damaged.

The mixer

The mash moisture level at the mixer should be approximately 11 % . When the mash has a lower moisture level than 11 % then water must be added at the mixer. Moisture levels at the mixer must not exceed 11 % in order to allow injection of sufficient amounts of steam to the mash to heat it to the desired temperature without reaching the choking point at the pellet mill level.

Monitor mash temperature and humidity at the mixer level every 2 hours. If the humidity level of the mash is less than 11 % then add water to bring it to a maximum of 11 %. If the humidity level of the mash is 11 % or higher do not add any water at the mixer.

The Conditioners

As a good rule of thumb we can expect an approximate temperature increase of 18 degrees Fahrenheit, (10 degrees C) for every .6 percentage increase in moisture to the mash. For mash with an acceptable level of say 11-12 % moisture, we can expect to be able to increase the temperature by at least 135 degrees Fahrenheit, (57 degrees C) above the ambient mash temperature without exceeding the 16.5% maximum moisture level before pellet mill will begin to reach the choke point. This means that in order to achieve our targeted objective of 195 degrees Fahrenheit, (90 degrees C), the ambient mash temperature must be at least 60 degrees Fahrenheit, (15.55 C).

Usually for many operations the conditioning time is marginal.   Longer conditioning times will help improve pellet quality and aid in achieving the desired minimum temperature objective Pressure regulators that are set too low are a common secondary problem to defective regulators insofar as precluding the achievement of targeted temperature objectives.

Steam quality being a very close second place contributor to the problem. Many of the conditioners currently in use are a single pass system. Mostly all single pass systems have difficulty in obtaining as uniform a mixture as the double pass conditioning systems. Most single pass conditioners also operate at atmospheric pressure. Systems that operate at atmospheric pressure can not sustain the conditions required for the higher quality steam that atmospherically pressurized systems do. An important aspect of this is the frequent and periodic checking of the condition of the steam nozzles. Steam nozzles can become clogged up and eventually blocked. This of course will have an adverse effect on the amount of steam available to heat the mash. The specific responsibility for generating the data along with commensurate accountability is usually inadequate for most feedmills. The method of analyzing the data and reporting it to appropriate departments is usually also inadequate or completely missing.

Action Line

The goal of a good conditioning operation is to blend steam and liquid additives into the feedstock in a continuous, even manner to provide a consistent feedstock to the pellet mill. The pitch of the paddles should be adjusted to provide the required retention time in the chamber so the steam can raise the temperature and moisture of the feedstock to the required level. Our required objectives are to be able to specifically raise the humidity level up to at least 16.0 to 16.5% and to raise pelleting temperature to at least 95 degrees centigrade.

Monitoring Points. *

Monitor inclination angle of conditioner paddles. Orient paddle inclination against the mash flow until a minimum of 2 minutes retention time is reached and maintain.

Monitor paddle shaft RPM and adjust to between 80- 100 RPM.

Monitor and have all steam pressure gauges in the conditioning room checked and/or calibrated for accuracy at least monthly. Replace immediately any nonconforming gauges.

Monitor mash humidity at the feed mixer level every 2 hours. If the humidity level is below 12% increase to 12 % level by adding water at the mixer level.

Monitor humidity and temperature levels at the entry level of the conditioner every 2 hour.

Monitor humidity and temperature levels at the exit level of the conditioner every 2 hour.

Monitor steam pressure at the regulator level every 2 hours. The pressure should be set not lower than 30 not higher than 45 PSIG at the regulator level. Initially we recommend the steam regulator be set at 35 PSIG.Make sure that the regulator is located as close as possible to the conditioner on the steam system line.

Paddle adjustment should also cause an even blending of additives into the feed. Monitor this quarterly, or as feedstock formulation varies significantly.

Monitor for bent paddles and paddle wear- weekly.

Monitor and clean magnet at least twice a day and each time the pellet mill door opens.

Keep mating surfaces of access doors clean monitor daily or as required so they can seal properly.

Monitor and Lubricate all bearings monthly.

Monitor all steam injection points to be sure they're not plugged at least weekly.

Monitor status and clean out the conditioner at the end of each shift to avoid a heavy build-up on the walls that will eventually fall off and perhaps plug the pellet mill. This minimizes wear on the agitator paddles and at the same time permit a smooth even flow of feed through the conditioning chamber guaranteeing a better pellet mill operation. It also minimizes cross contamination between feed batches.

The pellet mills.

Homogeneity of the pelleting equipment is important for spare part and service availability

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considerations. Please contact your equipment supplier for approved technical support

Goal- to form a durable, pellet of correct length from the loose, prepared feedstock.
Objective- Pellet to be stable in water for at least 6-8 hours. Durapell inclusion rate at mixer level to be reduced by 10-15% to reflect a maximum inclusion rate of 5.5 to 6.0 kilograms per metric ton.

Roller adjustment

This is the most important adjustment on a pellet mill. The pellet mill rolls are turned by frictional contact with the die, thus the roll must be adjusted down to a proper relationship with the die or it will not turn. The proper setting of the roll shell to the die face is critical to both production rates and pellet quality.

Therefore, the roll must be set as close to the die face as possible to prevent slippage and a plugged pellet cavity; yet, they cannot be set too tightly or they will roll the die inlet holes closed, penning the die, and eventually making pelleting impossible. Each roll is mounted on an eccentric shaft which is rotated to adjust the roll shell face outward to the die surface. Prior to making any roll adjustment, be sure that the inner surface of the die and the outer surface of the roll shell are clean and free of tramp material. The actual setting is dependent on both the type of roll shell used and how round the roll shell is manufactured by the vendor. Both corrugated or indented roller shells are normally ground concentric by the vendor and can be set in light contact with the die face to the point where the roller does not stop turning when the die is rotated 360 degrees. Hard faced rolls with a welded hard facing are not round and must be set so that the high spots of the roll just lightly touch the high spots of the die. Extreme care must be taken since severe damage could occur if too tight a roll setting is made. Excessive clearance in either the roller bearings or the pellet mill main bearings also can have a negative influence on roll setting and, thus, pellet mill production is affected. The flow of feed through the die wears the die down and away from the roll. Wear rate, is, therefore, a key factor in determining how often the rolls should be reset. With a very, abrasive pelleting operation, the roll should be set at least once a day. However, there are also many installations successfully pelleting that only set the rolls every few days, again dependent on formulation. Experience will dictate the best schedule. Monitor adjustments daily or as needed and include in pelleting room report.

Feed distribution

The purpose of the feed plow is to spread the feed uniformly across the die face ahead of each individual roll. This is important for both production rates and even die wear. The function of the plow is to divert the feed toward the back of the die, thus the plow must be positioned properly and it must be close to the die cover so the feed comes in contact with the plow and can be diverted. Feed plow wear is a critical factor and must be monitored at least weekly. There should be an effective seal between the feed spout and the rotating die cover at the entrance to the pelleting cavity so the feedstock; does not leak past the die and go directly into the cooler.

Monitor this weekly or any time there appears to be an excessive amount of fines going to the cooler.

Pellet cut off knives
They should be kept sharp to minimize fines generation. Blunt knives generate additional fines when they cause additional cracks in the pellet.

Pellet length is controlled when pellets are broken off at the die face as they come against the cut-off

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knives, thus a breaking rather than a cutting action. The customer specifies the actual pellet length required and that is posted with the pelleting work-order.
Monitor knife sharpness daily and correct as needed.

Shear Pins
They are designed to minimize shock loading when foreign material comes between the roll and the die. They should be positioned so the necked down shear area is located correctly at the joint between the rotating shear pin hub and the stationary base.. Use the right pin.

Lubrication, Maintenance of the Pelleting System

Oil lubrication
The oil level in a gear drive pellet mill must be maintained at the proper level, temperature, and cleanliness. The grade of oil used will be found in the vendor's pellet mill operations manual. Any oil meeting these vendor specifications is suitable for a minimum of 2000 hours of service life. To assure this service life, the oil must be kept clean; therefore, change the oil filter element when required (usually required when the pressure drop across the filter reaches 20 psig). Monitor the accumulated water from the oil sump weekly and drain once a month. Add clean oil to bring the oil level to normal. Monitor the oil level daily. Monitor oil temperature every 2 hors of operation. .Oil temperatures should not ever exceed 160 Fahrenheit, thus an oil cooler may be needed for most designs and applications.

Grease lubrication
Almost all pellet mill designs use grease to lubricate the roller assemblies. This is a severe heavy duty application for these bearings and requires a high grade grease. The type of grease required, the amount of grease required, and the frequency of lubrication are determined by the demands of each specific pellet mill application. Some of the factors are:

- The operating temperature.
- The load on the bearings-- Example: A light duty pelleting application like an integrated poultry application may only require greasing every 4 hours while a heavy duty mineral pelleting application may require greasing hourly). For Inasa we recommend greasing every 1 hours initially. This frequency can be reduced latter. A log is to be kept for maintenance purposes.
- The contaminating character of the feed being pelleted explains why the main and roller bearings should be greased with such frequency. The grease must be applied using pressure until grease is seen flushing out the bearing seals. The grease will flush contaminants from the bearings as well as lubricating them.

The most practical approach to use in establishing a greasing cycle is to begin with a one hour greasing frequency for both main and roller bearings (greasing until the seals on each bearing flush grease); and, then, reduce the frequency based on observations such as, how many pumps of grease does it take to purge each bearing.

Dies
Installation: A pellet die requires structural support to withstand the forces generated by the roller assemblies as they push feed through the die. This support comes from the die housing or quill on the heavier loaded - drive side of the die and from the die stiffener ring on the outboard side. Therefore, all mating surfaces of both the die and it's support structures must be cleaned before the die is mounted on the pellet mill. Secondly, the die fit for these mating structures must be checked for wear before the die is installed. The vendor's maintenance manual will provide the necessary details to check this, because, on all models, this support is critical whether it is a tapered clamp ring design (use the gauges supplied) or a

press fit/ replaceable wear ring concept. When the proper fit is not achieved, it is critical to replace the components immediately or face the higher costs of broken dies and their support structures. Eighty percent of all die breakage problems exist as a direct result of improper die fits.

Die wear and maintenance

The face of a die is worn away by the feed flowing through the die holes in much the same manner as sandpaper wears away the wood it touches. Therefore, grossly uneven die wear is due to poor feed distribution which, in turn, is due to worn feed plows, distributors out of adjustment, etc. This uneven wear reduces production rates and reduces the feed's retention time in the die which, in turn, reduces pellet quality. At best, a badly worn die should be removed, the face trued up (ground flat), and then reinstalled. At worst, the die should be discarded. The key answer to this problem is to keep the feed plows up to spec either by rebuilding with weld or by replacing these as well as any parts that are worn to the point where feed distribution is impossible.
Tramp metal is a significant factor in die life. Whenever tramp metal enters a die, at worst, the die breaks. At best, the metal fills the die holes and feed ceases to flow through the hole. This portion of the die does not wear down like the surrounding open holes. Besides reducing pelleting productivity through the die, those particular holes don't wear and begin to stand up above the face of the die. These plugged holes begin to look like a little volcano at this point. When these projections stand up above the die face, it is impossible to set the rolls properly, and the rolls slip. If the rolls are tightened to compensate, the die is more highly stressed. To avoid this situation, maintenance procedures must be established to punch out the tramp metal before the problem starts.

Whenever a pellet mill is shut down for an extended period of time, the die should be flushed with an oily mixture to condition and protect the die.

First, this procedure prevents corrosion in the die from moisture and acidic conditions, and it also reduces the tendency for the feed to bum and stick fast to the die hole. All of this makes the die start easily when production restarts. Example: Shut down and let a formulation such as a hog starter ration, with high sugar and/or whey, remain in the die. The sugars will rapidly heat due to the remaining temperature in the idle die and can eventually burn and stick to the die holes It will be virtually impossible to start feed through the die holes again. This is when a die can become penned as the operator tightens up the rolls to try and force feed through the burnt holes.

The Cooler

Goal: To remove the heat and moisture from the formed pellet so the pellet becomes hard and durable.
Objective: To bring pellet temperature to within 5 degrees of ambient temperature.

Other qualitative considerations can be analyzed in any cooling system. For example, a high volume low velocity auger system is better able to prevent damage to pellets exiting the pellet mill than high velocity low volume systems. The concept used in pellet cooling is similar to letting glue dry.
Pellets are in their most soft and fragile condition as they exit the pellet mill; therefore, the spout to the cooler must be kept free of obstructions that can cause pellet breakage. Proper distribution of

pellets across the entire pellet cooling area is critical for all designs or types of coolers whether vertical, horizontal, or counterflow design. Reason: The pellets are cooled and dried as air flows around each pellet removing the heat and surface moisture. Secondly, the cooling air will move through the areas of least flow resistance; thus, a higher level of pellets on one side of a cooler will restrict air flow and cause a warm pellet discharge. Pellet quality and the amount of fines going to the pellet cooler also have a direct impact on pellet cooling efficiency because the cooling air must have open spaces available in order to flow around each pellet. Excessive fines will plug these air spaces and limit air flow. A concentration of fines in one section of the cooler will greatly reduce cooling in this section; therefore, it is critical to have a vertical pellet drop into the cooler to minimize fines concentrations. A spreader may also be necessary. .

Attention to the pellet bed depth in either a horizontal or counterflow cooler is required because the pellets must be held in the cooling air stream long enough to give up the heat and moisture in the center of the pellet.

Counterflow cooling systems are normally able to do a good job. Any pellet cooling system should be able to cool pellets to within 5 degrees Centigrade from ambient temperature. Pellet temperature monitoring at cooler exit is essential for quality control purposes. Pellets must be cooled with air that is as clean from contamination as is possible. This dictates that the air intake apertures must be located in a clean area to keep pellets from being contaminated. Current intake position does not guarantee that intake air is clean. The exhaust air temperature and volume should be monitored. *Pellets treated with Dinapell require only 1 day to cure*.

Action Line

Pellet cooler Monitoring points:

- Monitor and correct monthly for any leaks in the cyclone, ductwork and fan areas.
- Monitor fan wear and resultant air flow reduction - quarterly.
- Monitor rotary valve wear at the cyclone discharge - quarterly; because, leakage through this valve will both cause cyclone dusting and will allow fines to accumulate in the toe of the cyclone where the swirling action will eventually wear away the metal.
- Monitor monthly for moisture and a wet fines buildup or an accumulation of pellets in the ductwork. This is a clear indication that there is not enough air flow in the system.
- Monitor and lubricate all bearings monthly.
- Monitor pellet and corresponding ambient temperature hourly. Note any non conforming situations for immediate action.
- Monitor the bed level in the cooler monthly or whenever hot pellets are discovered.
- Monitor the pellet cooler discharge at least monthly to be sure even cooling is achieved.
- Monitor pellet bed depth weekly using the specs in the cooler manual for reference.

Conclusion

Once the above steps are implemented we feel certain that at leat a 10 percent additional reduction in the use level for Dinapell can be achieved from projected dose levels along with some additional qualitative advantages such as achieving starch gelatinization . This will satisfy stated objective ranges. If any questions on the above please call direct at 770- 31-1309 ext. 131.

For all points to be monitored and as a minimum, a written log must be kept by the person designated incharge of the particular opersation. The log must reflect the following minimum information: Date and time of monitoring, other staff involved, if applicxable, objective measure and/or objective statement concerning status of monitored point. Signature of person incharge of operation. Copy of the log to be delivered to plant management and QC with the same periodocity as the points are monitored. Once a week person in charge of operation, plant manager and QC must meet to discuss overall situation/progress/ direction/problems etc...
See related Technical Publication # 21501002DPTPC; "**Testing Protocol for pellet quality"**

OTHER PRODUCTS OFFERED BY DINATEC FOR AQUACULTURE

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