The Impact of Feed Milling and Manufacturing Procedures on Nutrient Availability and the Importance of Quality Control

R. SCOTT BEYER, Ph.D.
Kansas State University
Department of Animal Sciences and Industry
130 Call Hall
Manhattan, KS 66506-1608
Phone: (785) 532-1201
FAX: (785) 532-5681
e-mail: sbeyer@oznet.ksu.edu

Introduction

All commercial broilers & turkeys are fed feed that has been pelleted. However, the exact economic benefit may not be well defined. Feed mills exist today as part of all integrated operations, and are looked at as a major cost center. Most have worked hard to reduce the cost of feed manufacturing. Unfortunately, this has resulted in cost cutting measures that perhaps have not resulted in the best quality feed. What is well known is that quality of feed and the way it is pelleted will impact feed conversion. Since feed is one of the highest costs of animal production, it is crucial that an effort be made to pellet feed most economically.

It is difficult to review literature concerning the effects of pelleting on mill and bird performance. Few studies have been conducted, and even fewer report adequate data to support their hypotheses.

And what about the hygienic quality of feed? The risk associated with pathogens passing from feed to growing birds is small but does exist. This is a risk factor which has potential to be extremely costly; however, this is not factored into feed milling practices in most poultry industries. Clearly we have ways to improve the hygienic quality of feed using different types of manufacturing methods of, but we must be willing to absorb additional feed manufacturing costs as well as make basic changes in the way feed is processed, handled, and transferred to the farm.

Commercial poultry have certain behavioral, physiological, and even anatomical traits that may require consideration when manufacturing feed. It is also possible that certain processing techniques will affect the bioavailability of some nutrients as well as impact the nutritional requirement of the bird. It has been recognized for many years that providing feed to poultry in the form of pellets could enhance the economics of production by improving feed conversion and growth rates. For this reason, feed for meat birds is processed into pellets or crumbles.

A survey of various literature sources indicates that pelleting results in improvements in feed conversion from 0 to 12 percent. Because the cost of feed is a substantial portion of producing meat, even small increases in feed conversion can increase economic returns. The cost to mix and manufacture feed must also be considered. These costs must not exceed the performance gains observed in the production of the birds.

Over the years, the basic manufacturing process for pelleting feed has remained virtually the same. At the same time, great changes have occurred in the meat bird industry. Producers no longer purchase feed from mills, instead feed milling exists as a part of an integrated, highly efficient production system. Thus, any emphasis on feed quality, a task originally undertaken by independent mills, has declined since feed is made >in-house=. Nutritionists now know the biological value of feed ingredients and the nutrient requirements of all poultry to the finest degree. Geneticists have improved the growth rate, body size, yield, etc. to levels once thought unattainable. However, even though it is well recognized that high quality manufactured feed will directly impact growth and feed conversion, the importance of feed quality has decreased priority.

During the past few years, a renewed interest by equipment manufacturers has resulted in significant changes in the way feed can be manipulated. The feed mill will have more flexibility to change processing parameters, which in turn could affect the nutrient profile of the feed. The purpose of this review is to the examine implications of poorly manufactured feed on production, and what changes are on the horizon.

Defining Feed Quality

Feed quality is defined using the *pellet durability index* (PDI). This is a simple test in which the pelleted feed is tumbled in a mixer for a defined period of time that simulates the transfer and handling of feed (Fairfield, 1994). The ratio of fines to pellets in the sample after tumbling is the PDI. Thus, feed with a higher PDI means that the manufactured pellets will more likely remain intact prior to feeding. Feed mills should use this method as a simple measure of pellet quality. Unfortunately, almost all of the previous literature reported in poultry publications focuses on the number of fines and pellets by weight, not the PDI. This makes it difficult, if not impossible, to interpret much of the available data on poultry feed quality. For example a diet screened to contain 100% pellets may only contain >soft= pellets which easily break apart during the feeding process, an observation that we have made in our research trials (Wilson and Beyer, 1998).

Many feed pellets are damaged by trucking, storage, augering and transfer to feed pans. Manipulation of the feed results in reduced pellet numbers, and in some cases, seriously reduces the total number of pellets that ultimately reach the feed pans. Because automated feed transfer and handling systems are necessary, it would seem that the best remedy for this situation is to increase the PDI of the feed using a different manufacturing process. It is important to reiterate that the PDI is a better measure of feed quality than the total number of pellets.

Pelleting and Management Considerations

Certain behavioral and anatomical traits of poultry must be considered during feeding. Pelleting reduces feed waste on the farm and this is due partially to avian anatomy. Birds obviously have no teeth and cannot swallow. Without teeth and with the need to use gravity to consume feed, broilers and turkeys cannot easily grasp food. Feed with uneven particle size increases waste since the smaller particles easily fall from the bird=s mouth. To fill the crop, a bird consuming fines or mash must spend more time standing to consume food, which decreases feed conversion since more energy must be expended to feed. Even feeder height is important, since setting above or below optimal will influence the amount of feed wasted. Indeed, our work has shown that feeder height may need to be lower than recommended if the feed quality is poor. Today=s birds are young and heavy and thus are able to stand for shorter time periods. Of course, there are other practical reasons for pelleting feed which include a reduction in dustiness, improved handling characteristics, increased physical density, and decreased stratification, among others.

Selection for increased body weight at a younger age has no doubt influenced basic anatomical and physiological traits. For example, the anatomical changes in the bird due to increased growth rate and size means that the oral cavity of birds has slightly changed. At first this may seem trivial, but this small change may influence feed spillage and feeding time.

It is also known that the anatomy of the digestive system is affected by feed particle size, which could impact nutrient absorption (Choi, et al, 1986). This is especially important considering that the digestive system of broilers and turkeys selected for rapid growth is less mature as the birds are pushed to market weight faster. Research is limited on the proper pellet sizes required by broilers and turkeys, and this may need to be addressed as feed manufacturing changes are made. We may have missed the importance of pellet length and size since current manufacturing methods often results in soft feed which may fall apart in an experiment or on a farm. When is the last time you worried about pellet *length*? It is likely that a refinement of pellet size to age or body weight can be optimized to improve performance.

Because birds have a keen sense of sight, feed particle size is also of importance. Studies indicate that birds desire feed in a larger size than mash. If provided a diet with equal portions of pellets and fines, the birds will consume the pelleted feed first. Poorly manufactured feed with excess fines results in some of the birds consuming only pellets, leaving the smaller fines for less aggressive birds. Because pellet quality affects the rate of growth, the presence of fines in a feed can affect flock uniformity and impact processing.

If fines are fed to poultry, a loss in feed conversion and rate of gain is observed (Blakely, et al, 1963, Brewer and Ferket, 1989, Moran, 1989, Waibel, et al, 1992). Almost as a rule of thumb, it would appear that older data indicate that with each additional 10% fines, a loss of almost one conversion point will result, which is also seen in broiler trials.

New Manufacturing Considerations

Because of the incidence of food borne pathogens, the desire to eliminate contaminated feed as a source of these bacteria may soon impact how poultry feed is manufactured. In the farm-to-table effort to reduce the incidence of food borne pathogens, sources of possible contaminants such as certain feed ingredients will be closely scrutinized (Pomeroy, et al, 1989).

The availability of new feed processing equipment that improves pellet quality and thus bird performance is also receiving attention. Fortunately, as we improve pellet quality by utilizing new equipment, feed hygiene will improve. This may also affect the way we currently use pellet binders and other additives to improve feed quality (Salmon, 1985).

Interest in alternative feed manufacturing methods has increased. These methods include the use of expanders, compactors, pressurized pelleting, etc. Interest in expanders in the U.S. has recently increased, although they have been in use in Europe for some time (Vest, 1996). An expander is a device somewhat similar to an extruder yet requires less energy and maintenance input. Briefly, the feed passes through a conditioning chamber and passes a thin gap between a cone shaped device and the chamber. The width of the gap and thus the mechanical pressure that is exerted on the feed is maintained by an adjustable hydraulic system. As feed passes the gap, a rise in temperature due to friction force occurs. Thus the feed not only undergoes a short-term temperature increase, but the feed particles have also experienced a shear force. Exposure to high temperature occurs for a short time so that destruction of heat sensitive nutrients appears to be minimal under standard conditions. Presumably, these factors may lead to an improvement in bioavailability of previously hard to digest feed components, while decreasing the microbial content of the feed (Peisker, 1994, Armstrong, 1993, Fancher, 1996).

Conditioning feed while under pressure is another method under consideration (Pelleting Concepts International, 1998). The increase in pressure allows the physical nature of steam to change thus increasing the temperature of steam to greater than 212 degrees F. This increases the gelatinization potential and presumably lowers the cost. Work in our lab has shown that this type of manufacturing greatly increases pellet quality (Wilson, et al, 1999a).

Wenger has recently begun testing a new piece of equipment that greatly increases gelatinization and thus feed quality. Work has shown that feed manufactured by this method increases bird performance (Wilson, et al, 1999b). Because the cost of feed is so important to the cost of production, it is likely that alternative feed manufacturing methods will be considered for producing poultry feed.

Nutritional Considerations

Although nutritionists have precisely defined the nutrient requirements for poultry, little work has focused on the effect of feed form on nutrient requirements. Jensen, et al (1965) determined that feed in pellet form increased the requirement for lysine in growing turkeys compared to when the turkeys were fed similar diets in mash form, especially when the lysine levels were formulated at marginal levels. Because pelleting increased the productive energy of the diet, the authors speculated that more lysine was required since the requirement of some nutrients is related to the level of other nutrients available to the bird. If the average increase in feed conversion due to pelleting is near 10%, for example, then the theoretical requirement for lysine for growing turkeys would be 1.43% compared to mash at 1.3% (NRC).

Somewhat troubling is the fact that many tables of nutrient bioavailabilities are based on feed in mash form that has not been processed. Thus, the performance of birds in the field fed poorly manufactured feed may differ from those fed diets with high pellet quality.

The nutritional considerations for adding an expander or other type of feed manufacturing equipment to the feed mill are numerous. On the practical side, an expander will allow the use of more feed components that reduce PDIs while eliminating the need for additives that improve pellet durability. Because some producers add fat post pellet, an expander would allow for more fat to be added at the mixer, eliminating the need to spray fat on the outside of the pellet.

Annular gap expanders produce high quality feed with greatly increased PDI=s (Wilson, et al, 1997). This is attributed to increased gelatinization of starch granules, which serve as glue to hold the feed particles together. However, little evidence suggests that increased starch gelatinization improve digestibility in poultry. According to Peisker (1994), expanders increase starch gelatinization, increase fat stability, increase metabolizable energy, decreased microbial contamination, and increase the soluble fiber. Fancher (1996) reported improved growth and feed conversion in male turkeys fed expanded diets compared to diets that were only pelleted. Data in our laboratory indicate that these parameters are improved by 5-10% when expanded diets are compared to conventionally pelleted rations in broiler trials. Some nutritionists were concerned that expanders could destroy certain heat sensitive nutrients, but work has shown that this is not much of a concern (Coelho, 1994)

Smith, et al (1995) found that there was no difference in true metabolizable energy due to expansion, although expansion increased feed conversion. This is similar to data reported for pelleted ration and is understandable if the energy gained by pelleting is due to productive energy gain rather than an increase in metabolizable energy. However, it would seem that the use of shear force by an expander would allow increased nutrients to be accessible which were previously bound within cellular material. Work in our laboratory has shown that increased amino acid bioavailability may occur when corn or soybean meal is expanded under different cone pressures. Increasing cone pressure led to a general increase in TME, aa availability, protein solubility and increased starch gelatinization. However, these products were processed separately, and further data is required to determine if an interaction of nutrients from different sources occurs in the gelatinization phase. The interaction of protein, starch and fat particles will likely be interactive when under pressure or at high temperature.

Considerations for Processing Soybean Meal

Soybean meal (SBM) is a crucial component of poultry rations since it is added to meet protein and amino acid requirement for growing birds. The use of SBM in poultry rations along with the availability of important amino acids in synthetic form allow the nutritionist to meet the requirement without the use of excess protein.

Soybean processing methods that result in a consistent, high quality product should also be considered. In the U.S., soybean meal is a valuable by product for the oil processors. Thus, these companies do the best they can to produsce meal that is neither under cooked or over processed. In fact, competition among these meal producers is becoming more intense, which has increased the quality of meals from the US.

Of course, soybeans also contain anti-nutritional compounds which must be destroyed prior to feeding poultry and other monogastric animals or they will substantially reduce growth and feed conversion. However, over heating soybeans during the roasting and oil removal steps could also reduce the nutritional quality. The combination of heat or moisture could lead to Malliard reaction products which could reduce the available to essential nutrients, most notable would be the amino acid, lysine. For most corn-SBM type rations formulated for poultry lysine is often a limiting amino acid and is usually added in a crystalline form in a least cost ration. Any circumstances which may lead to the destruction of essential amino acids lowers te economical value of soybean meal in a poultry ration. Since expanders alter the conditions of the feed manufacturing process, the bioavailability of certain amino acids in SBM is extremely important. Conversely, any manufacturing method which improves or increases the availability of these essential amino acids from SBM will increase the value of this product when formulated in a least cost ration. Because there is some early data which indicates that expanders improve feed conversion of broilers and turkeys, a series of investigations were completed to assess the effect of expander use for poultry feeds and SBM quality.

Initial research trials to demonstrate the effect of expansion processing on broiler growth, feed conversion, and carcass yield were conducted. Broiler chicks were housed and managed in a floor pen trial house (15 reps per treatment). Starter, grower, and finisher rations based on NRC (1994) estimates were formulated and fed in the form of conventional pellets or expanded processed pellets. The diets were formulated with 4.52, 4.00, and 2.51 % added soy oil, respectively.

The Pellet Durability Index (PDI) was substantially increased when the feed was processed with an expander prior to pelleting for all three diets. The modified PDI test, which simulates handling of pellets during transfer and feeding, indicated that the pellets made by expansion were better able to remain intact when compared to the conventional pellets and would generate fewer fines.

During the starter phase, body weight gain and feed efficiency (FE) were significantly increased when the birds were fed the feed in expanded form. Although the birds on expanded rations remained heavier throughout the trial, the difference was not significant during the grower and over all growth period. However, FE was significantly improved throughout the entire 49 day trial.

Expanding the feed did not improve overall carcass yield. The birds fed expanded rations tended to have more abdominal fat, however, the difference was not signicant.

A second series of experiments was conducted to determine the effect of varying conditioning temperatures and expander cone pressures. Broiler starter feed (Corn-SBM) NRC, 1994) was processed at 160, 175, and 190 degrees F in combination with 0, 6, 9, and 12 Kwh/ton of specific energy input to increase cone pressure of the expander. A significant amount of feed was required to equilibrate the feed manufacturing system between each change in parameter. Because the result PDIs were significantly different due to treatment, all products were ground to equal particle sizes prior to feeding. The feeding trial was managed as described previously.

Either increasing the conditioning temperature or increasing the specific energy input to the expander (thus increasing cone pressure) increased the quality of feed as measured by the PDI test. The data indicate that the PDI was maximized at 190 F and 9 Kwh/ton. The degree of starch gelatinization was increased as specific energy input to the expander increased. However, increasing the conditioning temperature of the mash did not improve PDI. This indicates that shear force or friction at the expander gap was significantly responsible for gelatinization of the starch which improved the pellet quality.

The growth and feed conversion for the broilers in Experiment 2 were more difficult to interpret. There were no significant main effects for conditioning temperature. Energy input significantly affected gain ($P <. 02$) but not FE. There was a significant interaction between temperature and energy for gain but not FE ($P < .01$). Thus there is a tendency for improved gain as temperature and energy increase, but the data is difficult to determine. However, it is interesting to note that the treatment with the highest degree of gelatinization (190 F and 9 Kwh/ton) also has the highest gain.

For Experiment 3, SBM was expanded without other additives using the parameters as describe previously. Unprocessed SBM, standard conditioned and pelleted, and expanded conditioned and pelleted samples were obtained. The samples (n=3) were dried, ground and analyzed for TMEn and available amino acids by the rooster method previously described.

The TMEn for each of the samples did not significantly differ. A high degree of variability was observed in the TMEn assay, although the data generally indicate a small increase in TMEn due to expansion processing. However, the data clearly indicate that the SBM samples that had undergone the expansion process had increased amino acid bioavailability. There was an overall increase in essential amino acid availability.

Monitoring Moisture

Moisture addition at the mixer has been shown to increase pellet durability and decrease pellet mill energy consumption for corn-soybean diets; however, the effect of this process on animal performance has not been tested. From a feed manufacturing standpoint, the objective of pelleting is to produce a high quality product with minimum production expense (Mommer and Ballantyne, 1991). Fairchild and Greer (1999) have demonstrated that increasing the moisture content of mash feed at the mixer subsequently decreased pellet mill energy consumption and increased pellet durability. Adding moisture to feed in this manner has never been evaluated through broiler performance trials. However, post-pelleted broiler feed mixed in high ratios with water has been shown to significantly improve broiler performance (Yalda and Forbes, 1996). Two studies were conducted to examine the effects of moisture addition at the mixer to mash and crumbled/standard pelleted diets on male broiler live weight gain (LWG), feed efficiency (FE) and mortality. Feed form and moisture treatments were applied to a (0-3) week battery study and a (0-6) week floor pen study. Crumbled/standard pelleted diets contributed to higher LWG=s and FE=s ($P< .05$) over mash diets in both studies. High moisture treatments contributed to higher FEZ ($P< .05$) in the (3-6) week period of the floor pen study over low moisture treatments. Broiler death was affected only in the (3-6) week period of the floor pen study, where standard pelleted diets produced higher mortality ($P< .05$) over mash diets. These results conclude that high moisture pelleted diets are beneficial to bird performance when fed in the (3-6) week grower period and crumbled/pelleted diets are superior to mash throughout broiler rearing.

The quality of manufactured poultry feed has not received adequate attention. Most feed manufacturing research is based upon feed that was processed by older methods and the results may not be reliable. Feed form interacts with bird behavior, management, anatomical changes, etc, and may even influence the requirement of certain nutritional components. Properly manufactured feed will improve growth, and feed conversion, as well as product quality. The impact of feeding conditioning and processing on nutrient availability needs to be determined to increase the precision of feeding programs to reduce costs optimally. Refinements in crumble quality, pellet diameter and pellet length could lead to increased efficiency. Least cost feed formulation should consider the impact on feed quality and bird performance.

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