Effect of Feed Manufacturing Practices on Nutrient Availability and Feed Quality

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Importance of manufacturing quality feed

It is commonly accepted that pelleting poultry rations increases weight gain and improves feed efficiency. Pattern, Buskirk, and Rauls (1937) were the first to report that pellet-fed birds performed better than mash-fed birds, and since then, numerous researchers have confirmed their findings. While the benefits of pelleting on growth performance are well-documented (Calet, 1965; Moran, 1989; Jensen, 2000), the improved handling characteristics of feed (Thomas and van der Poel, 1996) are attractive to feed manufacturers and live production managers. Pelleting increases the bulk density of the ration, allowing more tonnage to be delivered per truck. Pellets have enhanced flow properties that allow for good conveying by screw agars, as well as improved discharge behavior from feed bins due to reduced bridging compared to mash. The matrix created by starch gelatinization and protein denaturation during processing allows for ingredients commonly known to segregate, such as limestone, to stay fixed within the pellet. It should be considered that excessive levels of fines in a diet will discount the advantages of pelleting on feed handling characteristics.

Response in weight gain and feed efficiency of birds fed pelleted diets is substantially improved when the diet is of good pellet quality, i.e. high pellet durability and low levels of fines. Proudfoot and Sefton (1978) reported that body weight and monetary returns were inversely related to the proportion of fines in finisher diets. Manufacturing diets of good pellet quality is a difficult task in an industry that requires high production rates from its feed mills; therefore growth performance is often sacrificed at the expense of feed mill throughput.

Increasing throughput by reducing residence time in the conditioner, increasing feed rate to the pellet mill, or through changes in roller/die dimensions can reduce the extent of heat transfer to the meal, as well as friction and shear occurring in the die. Extent of protein denaturation and starch gelatinization will be lessened due to increased throughput, leading to the diminished binding of particles. A reduction in pellet durability and hardness will result from a lack of particulate binding, resulting in the creation of feed fines. Proudfoot and Sefton (1978) observed a 5% decrease in 49 d body weight when comparing male broilers fed pelleted diets containing 45% fines versus 25% fines. This depression in body weight at the higher level of fines is of substantial significance, considering field surveys such as that of Scheideler (1995) have reported instances of birds receiving feed with as low as 28 to 37% intact pellets.

Productive energy mediates response to pelleting

Since it is recognized that broilers do not exhibit a benefit in growth from pelleted diets containing high levels of feed fines, it can be concluded that the presence of intact pellets is of greater importance than the actual physical and chemical changes feed undergoes during processing. The preference for pelleted diets over mash tends to increase with bird age, suggesting that older birds desire a feed in particulate form in order to conform to changes in dimension of the oral cavity (Moran, 1989). While it is conceivable that the improvement in performance is the result of increased diet digestibility, research has shown that when pelleted diets are re-ground to the consistency of mash, the growth response to pelleting is eliminated (Hussar and Robblee, 1962). The potential for deactivation of antinutritional factors, increased susceptibility of starch to α-amylase, increased solubility of non-starch polysaccharides, and destruction of cell walls through mechanical shear does not appear to outweigh the benefits of the pellet's physical presence.

Increased appetite has been suggested as an explanation for the response to pelleted diets. Hamm (1960) accounted faster growth rates to increased feed consumption, and suggested that birds with higher body weights would have increased maintenance requirements. Jensen *et al*. (1962) observed that chickens fed mash and pelleted diets consumed approximately the same quantity of diet, but pellet-fed birds spent less time in the act of consuming meals. Recent studies using modern strains of commercial broilers have reported similar responses in feeding behavior (McKinney and Teeter, 2003). It could then be concluded that the increased growth rate of birds fed pelleted diets is accounted for by a reduction in energy expenditure during meal consumption.

Reddy *et al*. (1961) observed that chicks fed pellets spent approximately 4% of their day in the act of consuming feed compared with 15% for mash-fed birds. Reduced energy expenditure would allow for an increase in productive energy (PE) value of the diet, thus providing more calories for protein and lipid synthesis in growing birds. Reddy *et al*. (1962) reported that mechanically increasing diet density through the pelleting process did not affect dietary ME, but markedly increased PE. Absence of an improvement in ME suggests that pelleting does not improve the digestibility of dietary components, while the increase in PE value indicates a decreased heat increment with feeding pellets. While birds fed pelleted diets tend to consume more feed, this is not an absolute. A growth response is often detected despite there being no substantial difference in feed intake. Therefore, reduced energy expenditure during meal consumption is most likely the significant factor eliciting the growth response observed with pellet-fed birds.

Pellet quality and subsequent bird performance

In order to realize a benefit in growth performance, it is important to manufacture a diet of high pellet durability that will not generate a substantial quantity of feed fines during transportation and handling. Diet formulation is typically the largest contributor to pellet quality. The critical role of diet formulation is confirmed by the beneficial effects of wheat or waxy endosperm corn inclusion on pellet durability (Froetschner *et al*., 1998; Traylor *et al*., 1999). In general, it should be recognized that conditioning and pelleting do not favor extensive starch granule solubilization. Viscoelastic properties due to hydration and partial development of the gluten fraction primarily contribute to particle binding, while the benefits of starch gelatinization on pellet stability often appear to be secondary. Therefore, high protein cereals such as wheat will contribute to pellet quality more readily than corn.

Dietary fat is known to have an inverse relationship with pellet quality, thus affecting broiler performance (McKinney and Teeter, 2003). Added fat coats starch granules, thereby shielding water uptake and impairing heat transfer necessary for gelatinization. Reduced friction in the die resulting from the lubricating action of fat will further diminish the extent of starch gelatinization. While addition of fat to broiler diets at the mixer is uncommon in the industry, substantial use of animal by-product meals, as well as ingredients such as high-oil corn or full-fat soybeans can reduce pellet quality in a similar manner. High levels of dietary fat necessitate the use of pellet binders when corn is the primary cereal in the diet. Sodium bentonite and calcium lignosulphonate can provide stability to pellets in the presence of high fat levels (Moran, 1989), yet neither provides any substantial nutritional value to the diet. Dietary inclusion of wheat or wheat milling by-products is a cost-effective means of adding a pellet binder with nutritional properties.

It has been suggested that particle size of the mash is another critical factor in the pelleting process. Particle size preference of poultry has been extensively researched, with much of the work being conducted with mash diets. While an optimal particle size may be determined with a mash diet, conditioning and pelleting that same mash will physically alter the particle size, thus influencing feed intake. Therefore, it is important to determine the effects of particle size on pellet quality and subsequent bird performance.

Kilburn and Edwards, Jr. (2001) observed that feeding coarse ground corn in a mash diet improved calcium retention, yet no advantage was noted when the same diets were crumbled or pelleted. Bayley *et al*. (1968b) reported that steam-conditioning and pelleting corn, soybean meal, and wheat bran-based diets increased phosphorus availability as measured by bone ash. The authors suggested that the increased phosphorus availability may negatively affect the calcium to available phosphorus ratio, thus interfering with calcium absorption. This could have attributed to the lack of a calcium retention benefit when coarse particle size diets were crumbled or pelleted. In one experiment, Kilburn and Edwards, Jr. (2001) observed that mash diets with fine corn particles had a higher ME content than did diets with coarse particles, yet the difference was insignificant when diets were pelleted.

Grinding the primary cereal grain in the diet to a fine particle size is often assumed to increase the surface area of starch granules for interconnecting protein fibrils, thus improving pellet durability. Reece *et al*. (1986 a, b) determined that grinding corn to a fine particle size or to the same fineness, as the other dietary ingredients did not affect pellet durability or broiler performance. In a common cited study, Nir *et al*. (1995) reported that particle size maintained its effect on performance even after pelleting, yet the authors made no remarks as to pellet durability of the diet or percent feed fines that may have had an influence on performance. Martin (1983) found that increasing particle size had little affect on pellet quality. The slightly higher pellet durability obtained by grinding corn or sorghum through a 3.2 mm hammermill screen was offset by the energy cost of grinding with a 3.2 mm screen. It would appear that the effect of varying cereal grain particle sizes on pellet durability may be less of a concern than the energy costs and throughput restrictions associated with grinding for a desired degree of fineness.

Feed form and amino acid needs

Research has shown that the ME value of a diet with good pellet quality may be reduced without affecting growth response (Howlinder and Rose, 1992; McKinney and Teeter, 2003). When the extra-caloric value associated with feeding pellets is not taken into account, more energy is partitioned towards lipid synthesis, as opposed to protein synthesis, resulting in the increased incidence of abdominal fat commonly reported in studies comparing mash and pellet feeding. If reduced energy expenditure from consuming pelleted diets is known to increase calories available for growth, it is conceivable that dietary amino acid concentrations should increase proportionally in order to realize maximum protein synthesis.

Bayley *et al*. (1968a) observed that feeding broilers crumbled diets low in crude protein supported lower body weight gains than when those diets were fed as mash. Increasing dietary crude protein from 18% to 23% alleviated the depression in weight gain for the crumble-fed birds and supported greater gains than those achieved with mash diets. Dietary lysine concentration is of particular concern due to the notable effect that lysine has on energy partitioning and protein retention (Batterham *et al*., 1990). Feeding a pelleted diet marginal in lysine has been shown to accentuate a lysine deficiency in turkeys (Jensen *et al*., 1965), thus suggesting an imbalance between lysine and PE.

Superior performance obtained with high lysine, pelleted diets

A recent study conducted by Greenwood *et al*. (2003) illustrates the effects of reduced energy expenditure from consuming pelleted diets on digestible lysine needs for optimal growth performance of broilers from 16 to 30 d. The factorial treatment arrangement was achieved by feeding diets in two forms (mash and pellets) with five levels of digestible dietary lysine (0.75, 0.85, 0.95, 1.05, and 1.15%).

Maximum weight gain for pellet-fed birds was achieved at the 1.05% digestible lysine concentration (Figure 1). No improvement in growth response was realized by feeding mash diets with digestible lysine concentrations greater than 0.85%. The lower feed efficiency (Figure 2) obtained at the 0.75% level when the diet was fed in the pelleted form supports the findings of Jensen *et al*. (1965). Pelleting a diet marginal in lysine resulted in a perceived lysine deficiency as noted by the reduction in feed efficiency. Feed efficiency of mash-fed birds was not improved by feeding digestible lysine concentrations over the 0.95% level, while maximum feed efficiency of pellet-fed birds was obtained at the 1.15% level. Pellet-fed birds consumed significantly more feed ($P<.0001$), with the difference in intake being approximately 40 g. Calories consumed per bird were calculated from average feed intake, thus pellet-fed birds consumed more dietary energy than mash-fed birds.

Feeding pelleted diets increases estimated lysine needs

To determine if feed form has an influence on estimated lysine needs, exponential regression curves were fitted to the experimental data points for weight gain and feed efficiency using the equation described by Schutte and Pack (1995). Estimated digestible lysine needs for weight gain and feed efficiency were calculated at 95% of maximum response lysine supplementation for each feed form. Birds fed pelleted diets required 13% and 9% more digestible lysine than mash fed birds for optimal body weight gain and feed efficiency, respectively.

A large proportion of studies focusing on amino acid needs of broilers are conducted by research groups using mash diets due to limitations such as the lack of steam-pelleting capabilities, additional costs of pelleting, and the use of unconventional feed ingredients that may negatively affect pellet quality. Differences in growth response between mash and pellet-fed birds may be attributed to the substantial variation in digestible amino acid recommendations that currently exist in the literature. Application of amino acid recommendations obtained using mash diets to an industry situation where good pellet quality exists may result in increased days to target weight, as well as lower feed efficiency due to an underestimation of the bird's amino acid needs.

Greater lysine needs of the pellet-fed birds suggest that feeding diets of good pellet quality is responsible for more calories being made available for growth. Since pellet-fed birds are often noted as having a higher proportion of abdominal fat than mash-fed birds, increasing the lysine content of pelleted diet should be of great economical importance by improving dressing percentage and breast meat yield while decreasing body fat deposition.

The growth response associated with feeding a pelleted diet is often attributed to a reduction in energy expenditure during meal consumption (Jensen, 2000). In the present study, the significantly greater feed intake of pellet-fed birds resulted in an increase in calories consumed per bird. While pellet-fed birds may expend less energy during feeding, an additional 127 kcal is being consumed by pellet-fed birds. Paired feeding trials conducted by Hamm and Stephenson (1959) determined that feeding pellets equivalent to mash intake resulted in no growth response, suggesting that the added growth and feed efficiency are due to increased feed consumption.

Preliminary work conducted at Kansas State University has suggested that feed form does not affect total sulfur amino acids (TSAA) needs to the extent that was observed with lysine, yet pellet-fed birds were more efficient in the their conversion of

TSAA into body weight gain. While it is important to determine the influence that pelleting diets has on estimated nutrient needs, it is important to investigate the role of feed fines on nutrient intake and utilization. Current research at Kansas State University has observed that bird performance has an inverse relationship with feed fines level in the diet. When dietary lysine concentrations were increased, performance at high levels of fines was improved (Figure 3). These findings suggest increasing nutrient density may compensate for inferior performance obtained with diets of poor pellet quality.

Conclusions

While it is accepted that feeding pelleted diets improve broiler performance and pelleting is commonly practiced by the industry, the influence of feed form should be of greater concern when designing research studies. Since the modern broiler has been heavily selected for maximizing feed intake, bird response to pelleted diets and the subsequent data generated from today's feed form studies may differ greatly from those obtained in the 1960's with standard breeds and earlier genetic lines of broilers. More research is necessary to determine effects of pellet durability and percent feed fines on nutrient needs.

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Figure 1: Influence of feed form and digestible Lys interrelationship on weight gain from 16 to 30 d

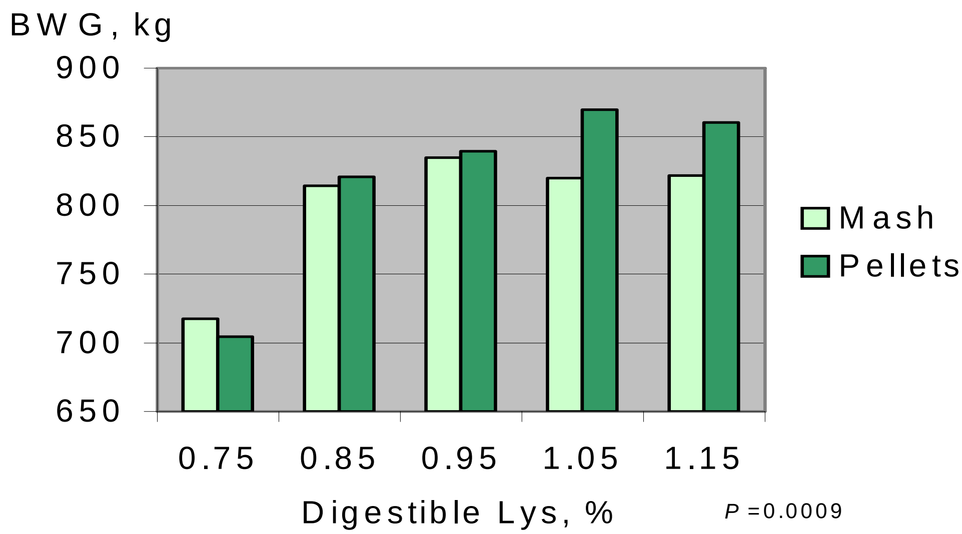

Figure 2: Influence of feed form and digestible Lys on feed efficiency from 16 to 30 d

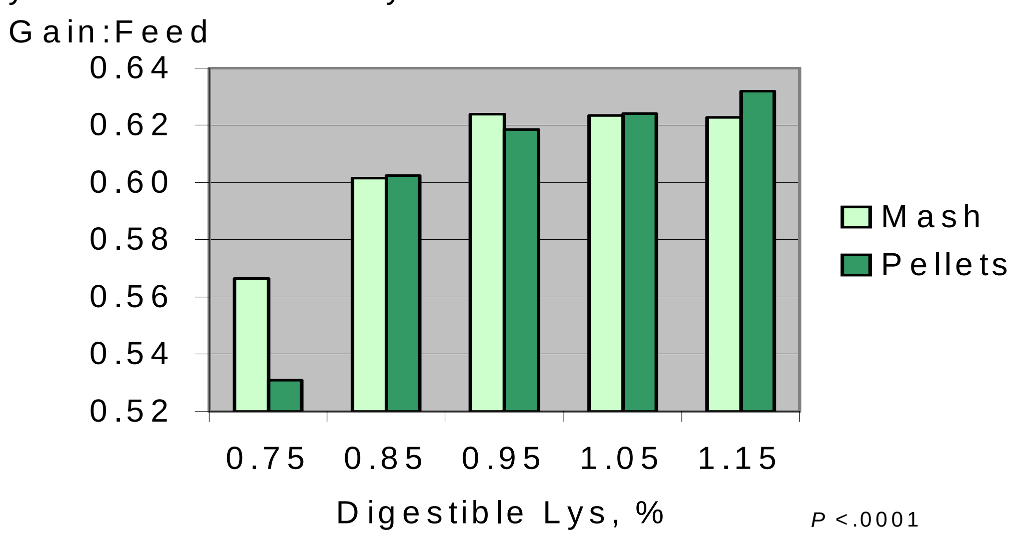

Figure 5. Effect of feed fines level and lysine concentration on BWG of male broilers from 14 to 30 d.