Maintaining Feed Quality

Joe S. Moritz, PhD
Associate Professor of Poultry Science and State Extension Specialist
West Virginia University

The production of high quality pellets significantly improves animal performance and impacts customer perceptions of the quality of feed being purchased. For an independent feed company that sells to producers, feed quality perceptions are obvious. However, for integrated animal production operations, realizing that investment in improving pellet quality translates to economic gains upon feeding is more challenging. However, it is essential that both independent and integrated mills utilize manufacturing techniques that produce high quality pellets without affecting heat sensitive nutrients. Balancing variables such as pellet quality, through-put, variations in ingredients, ambient temperature, and heat sensitive nutrients make feed manufacture a complicated and important facet within animal production.

The binding of pellets requires that nutrients within the diet formulation undergo conformational changes. Most notably, the gelatinization of starch, denaturation of protein, and solubilization of fiber contribute to pellet binding. In order for these conformational changes to occur, thermal processing is necessary (high temperature, moisture, and pressure). Several variables in the feed manufacture process contribute to thermal processing: die specifications, conditioning temperature and time, through-put, ingredient particle size, and diet formulation (Reimer, 1992 and Moritz, 2007). These variables can also induce conformational changes in amino acids, vitamins, and exogenous feed enzymes, decreasing their nutritional value to the animal. Interactions between variables make understanding individual variable effects on pellet quality and nutrient availability very difficult. When reviewing past literature that focused on feeding diets that vary in pellet quality, it is difficult to separate feed form and nutrient availability effects. Recent work, conducted at West Virginia University, acknowledged this problem and attempted to isolate feed form effects on economics of broiler production (Lilly, *et. al*., 2011).

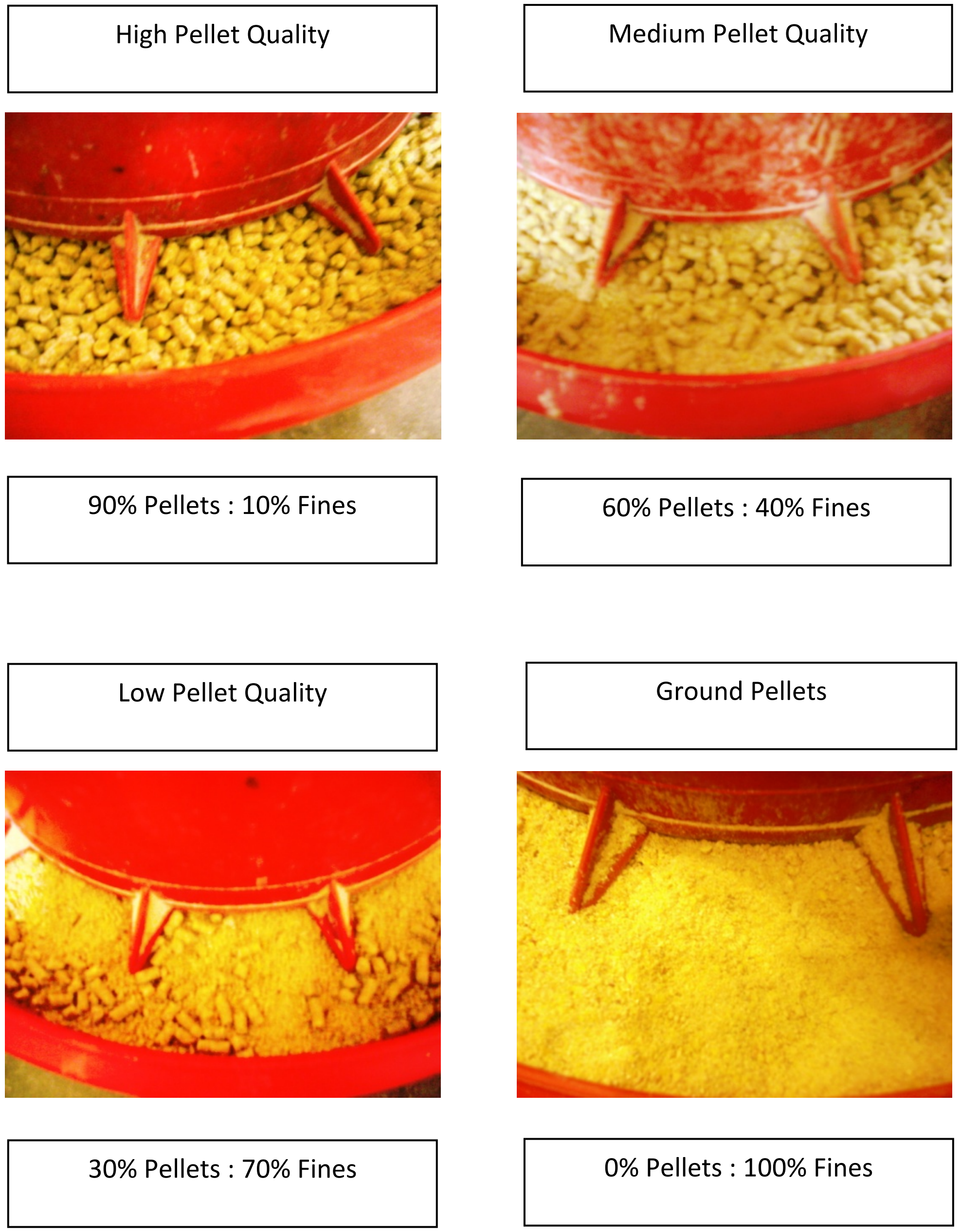
The objective of the current study was to explore feed form affects on modern day Cobb-500 broiler performance when nutrient availability was consistent among treatments.

Methodology

Four variations in feed form were manufactured and fed to Cobb 500 broilers in the growing period from day 21-38. Broilers were fed a common starter diet from day 1- 20. All diets were manufactured at the West Virginia University pilot feed mill. Feed manufacture was simplified to not confound the treatments with any thermally induced nutritional effect. Diets were corn and soybean meal based, formulated to National Research Council guidelines, and contained 3% mixer added fat. Recent research from our laboratory has shown that increased levels of mixer added fat, i.e. 3%, can alleviate negative nutritional effects generated by friction/heat within the pellet die, especially when techniques are utilized to produce high quality pellets.

The pelleting technique used in this study included a slow production rate (within the pellet mill manufacturer's recommendation), a thick pellet die (1.77 x 3/16"), a high steam conditioning pressure (80 psig) prior to the conditioner, and a high steam conditioning temperature (200^{o}F). This technique created a high quality feed with 90% pellets and 10% fines. Variations in pellet quality were created by grinding a portion of the high quality pellets via roller mill to produce fines. Fines were then mixed with intact pellets to create different pellet to fine ratios (%pellets:%fines). The four feed form treatments were high pellet quality (HPQ) 90:10, medium pellet quality (MPQ) 60:40, low pellet quality (LPQ) 30:70, and ground pellets (GP) 0:100 (Pictured in Figure 1).

Figure 1. Four Variations in Feed Form



Results and Discussion

The Cobb 500 broilers had decreased feed conversion ratios when fed diets containing intact pellets. The highest carcass weight (day 39) was obtained when broilers were fed HPQ in comparison to all other treatments. The modern broiler appears to respond best to an improved feed form by increasing feed intake, and consequent live weight gain, with improved feed conversion being more of a minor response. An economic model that set feed costs at $300/ton multiplied by feed intake/[(carcass weight) – (60% x 21d chick weight)] found a savings of $0.02 per pound of carcass weight when feeding HPQ versus GP (Table 1). In addition, a linear model generated from the data indicated that with each ten percentage point increase in intact pellets there was a 0.4 point improvement in FCR, a 0.35 oz increase in carcass weight and a 0.14 oz increase in breast weight. It should be noted that the MPQ and LPQ treatments in this study were composed of large, intact pellets that achieved a pellet durability index of 90%. In a practical industry setting, a diet containing 60 or 30% pellets (consistent with the MPQ and LPQ treatments) would be composed of pellets with inferior structural integrity and size. This research explored all combinations of the established benefits of feeding pellets except for ingredient segregation and increased pellet length effects. If ingredient segregation and pellet length effects were included in the design of this study, then the benefits of feeding high quality pellets would likely be more dramatic. In addition, birds used in this study were only grown to 39 days. A longer grow-out period may accentuate feed quality benefits.

Table 1. Economic analysis using high and low feed costs, 21-38 day feed intake, and 39 day carcass weight

Feed Form treatments (pellet : fine)	$/lb of carcass weight[1] (Feed Costs: $300/ton)	Relative difference between GP and pelleted treatments ($/lb) (Feed Costs: $300/ton)	$/lb of carcass weight[1] (Feed Costs: $200/ton)	Relative difference between GP and pelleted treatments ($/lb) (Feed Costs: $200/ton)
GP (0:100)	0.371	00	0.247	00
LPQ (30:70)	0.365	-0.006	0.243	-0.004
MPQ (60:40)	0.366	-0.005	0.244	-0.003
HPQ (90:10)	0.350	-0.021	0.234	-0.013

$$\text{\$/lb of carcass weight} = \frac{\text{\$300 or \$200}}{\text{2000 lbs feed}} \times \frac{\text{feed intake}}{[(\text{carcass weight}) - (60\% \times 21 \text{ d chick weight})]^{1}}$$

[1]60% of 21 d chick weight is a proposed carcass weight achieved from 1-21 days

Take Home Message

These data may encourage a company to consider if an investment of time, utility cost, and labor to produce pellets of high quality would justify improvements in live production and overall profitability. More specifically, the feed mill may have to operate an additional day per week or additional shift, and electrical and gas inputs at the mill would likely increase. Throughput may be enhanced via increased inclusions of mixer-added fat or high-fat ingredients such as distillers dried grains with solubles or bakery by-product meal. However, pellet quality effects must be considered. If feed manufacture strategies translate to improved bird weight gain, and less feed and time are required for grow-out, then the added investment required to create pellets of high quality may be well justified.

The next issue for a feed mill to address is how to achieve high pellet quality within the constraints of their current production system. Many strategies to improve pellet quality have been established and new strategies are continually being developed. These strategies may be implemented alone or in combination with one another. In addition, strategies to improve pellet quality may allow for an assessment model to be created in order to estimate whether or not an investment in pellet quality is justified for a particular operation.

Possible Strategies to Create High Quality Pellets

1. **Slow down production rate.**

   Slower through-put allows for greater retention time of feed in the pellet die that will increase thermal reactions in nutrients and thus feed particle adhesion. The end result of this strategy would be the production of higher quality pellets (Buchanan and Moritz, 2009; Lilly *et al*., 2009).

2. **Decrease corn particle size.**

   Smaller corn particle size increases surface area for feed particle adhesion and improves pellet quality (Reece *et al*., 1986, Wondra *et al*., 1995).

3. **Use a thicker pellet die.**

   Greater die thickness creates improved retention time of feed in the pellet die, thermal reactions in nutrients, feed particle adhesion and pellet quality (Buchanan and Moritz, 2009; Hott *et al*., 2008).

4. **Increase steam conditioning temperature.**

   Increasing moisture and heat increases feed particle adhesion and pellet quality (Cutlip *et al*., 2008; Lilly *et al*., 2009).

5. **Use a pellet binder.**

   Commercial pellet binders are available. A binding agent could be as simple as added moisture at the mixer. Additionally, recent research has demonstrated that protein pastes derived from waste products of fish processing may provide pellet binding benefits as well as nutritional benefits in the form of highly available amino acids (Fairchild and Greer, 1999; Hott *et al*., 2008; Buchanan and Moritz, 2009; Gehring *et al*., 2009).

6. **Manipulate diet formulation.**

   Least cost diet formulation often may not enhance pellet quality. Manipulating diet formulation to increase pellet quality, although potentially increasing diet cost, may decrease overall production cost, if pellet quality and subsequent live performance are significantly improved. However, caution should be exercised not to create diet formulations that increase frictional heat within the die to a degree that reduces nutrient availability (Briggs *et al*., 1999; Buchanan and Moritz, 2009; Gehring *et al*., 2009; Lilly *et al*., 2009).

Most industry leaders are well aware of these somewhat intuitive strategies to improve pellet quality. The more challenging issue is assessing if investment in pellet quality is cost effective to the integrated operation. Many of the strategies can be easily implemented during short test periods at the mill. During these test periods, simple variables such as estimates of production rate and electrical energy usage can be collected. This information used in conjunction with pellet durability data (pellet durability tester ~ $250) and live performance data from past research may provide a basis to defend or refute an investment in pellet quality. If this task seems daunting, then consultation may be appropriate.

Finally, consideration should be given to whether or not the strategies implemented to improve pellet quality may have a negative effect on nutrient availability. Many strategies to improve pellet quality involve increasing thermal reactions in nutrients and consequent feed particle adhesion. These interactions are advantageous to improving pellet quality, but caution must be exercised to prevent nutrient availability from being decreased. More specifically, conditions of high heat and moisture may also induce non-favorable reactions that lead to reduced nutrient availability (e.g., reduced protein solubility, vitamin oxidation, Maillard reaction, and exogenous enzyme degradation). If non-favorable reactions persist then benefits of pelleting could be reduced or completely negated, thus undermining the investment to improve pellet quality. Past research has illustrated that if pelleting strategies do not account for the potential to reduce nutrient availability then benefits of high quality pellets can be substantially diminished. Some examples of this situation include Buchanan and Moritz, 2009; Lilly *et al*., 2009; and Beaman *et al*., In press.

A specific example of how feed manufacture technique can decrease nutrient availability can be demonstrated with recent research from West Virginia University. The objective of this study was to identify feed manufacture techniques that alter lysine availability as indicated by feeding broilers in the finishing phase. Feed production rate, pellet die specification, and level of mixer-added fat (MAF) influence feed exposure to pellet die heat and pressure that may alter chemical structures of ingredients. Lysine has been indicated as a nutrient with potential to be structurally altered, especially in the presence of heat and reducing sugars, as in Maillard reactions, that decreases nutrient availability. A practical diet containing 7.5% bakery by-product meal and 0.13% lysine HCL was formulated to 90% lysine recommendations of Cobb-Vantress in order to best demonstrate lysine availability differences when manufactured and fed. This diet was utilized in a 2x2x2 factorial design that evaluated the effects of production rate (0.6 or 0.9 ton/hr), die thickness (1.5 or 1.77”), and MAF level (0.5 or 3%) on feed manufacture, broiler performance, and processing yield. Two additional treatments: unprocessed mash and double pelleted (exposed twice to 0.6 ton/hr production using a 1.77” die after 0.5% MAF) were also manufactured and fed. All diets, excluding mash, were steam conditioned at 82^{o}C and reground prior to feeding. Pellet mill electrical energy usage, pellet quality, and bulk density were increased with 0.6 ton/hr production rate, 1.77” pellet die, and 0.5% MAF techniques ($P=0.0001$) that created greater feed exposure to pellet die heat and pressure. Regardless of these effects, upon feeding, no differences in performance or processing yield were observed among treatments in the factorial structure ($P>0.05$). Contrasts demonstrated that birds fed unprocessed mash had decreased feed conversion ratio compared to double pelleted fed birds, with birds fed diets from the factorial treatments being intermediate ($P<0.05$). These data suggest that pelleting in general had deleterious effects on nutrient availability that could not be identified by varying feed exposure in the die. Based on performance measures, it was unclear whether or not lysine or other nutrients were affected.

Table 2. Live performance variables of broilers fed diets that varied in manufacturing technique and level of total lysine (Shipe et al 2011)

Treatment[1]	D 23 Pen Weight (kg)	D 42 Ending Body Weight (kg)	Mortality (%)	Bird Weight Gain (kg)	Pen Feed Intake (kg)	Feed Conversion Ratio (kg/kg)
Fast, 1.77", 0.5% MAF[2]	12.805	1.798	3.75	1.188	44.608	$2.01^{c,d}$
Fast, 1.77", 3% MAF[2]	12.858	1.772	3.75	1.176	45.937	$2.01^{c,d}$
Fast, 1.5", 0.5%MAF[2]	13.029	1.783	2.53	1.148	43.781	2.02^{c}
Fast, 1.5", 3% MAF[2]	12.913	1.751	1.91	1.113	43.664	$2.04^{b,c}$
Slow, 1.77", 0.5% MAF[2]	12.875	1.825	1.25	1.193	46.287	$1.99^{c,d}$
Slow, 1.77", 3% MAF[2]	12.968	1.770	1.25	1.138	44.982	$2.02^{b,c}$
Slow, 1.5", 0.5% MAF[2]	12.648	1.810	3.16	1.186	44.099	$2.00^{c,d}$
Slow, 1.5", 3% MAF[2]	12.833	1.746	2.50	1.124	43.294	$2.01^{c,d}$
80% Lysine[3]	12.902	1.689	1.88	1.061	43.705	2.12^{a}
Unprocessed Mash[2]	12.451	1.803	5.16	1.236	43.105	1.94^{d}
Double Pelleted[2]	12.774	1.807	3.13	1.201	47.785	$2.09^{a,b}$
ANOVA P value	0.8377	0.7713	0.7254	0.3929	0.4950	0.0006
Fisher's LSD[4]	--	--	--	--	--	0.0726
SEM[5]	0.1989	0.0468	1.3821	0.0459	1.4867	0.0258
Main effects and interaction probabilities of the factorial treatments						
Production Rate	0.5931	0.7506	0.2573	0.9132	0.8693	0.4109
Die Thickness	0.8759	0.6080	0.9763	0.3936	0.0924	0.6542
MAF Level	0.6829	0.2323	0.6992	0.2613	0.8263	0.3518
Production Rate x Die Thickness	0.2253	0.9785	0.0655	0.5768	0.8491	0.5720
Production Rate x MAF	0.5169	0.6801	0.9921	0.6342	0.4177	0.8735
Die Thickness x MAF	0.8853	0.9203	0.6992	0.8352	0.8168	0.9541
Production Rate x Die Thickness x MAF	0.6196	0.9856	0.9921	0.9218	0.6342	0.5688
Contrasts						
Unprocessed Mash vs. Factorial Treatments	0.0526	0.6681	0.0743	0.1157	0.3521	0.0106
Double Pellet vs. Factorial Treatments	0.6653	0.6134	0.6772	0.3868	0.0456	0.0059

[a-d]Values within comparisons with different superscripts differ (P≤0.05)

[1]Treatments vary based on production rate, pellet die thickness, and percentage of mixer added fat

[2]Formulated to 90% of Cobb's lysine recommendations

[3] Formulated to 80% of Cobb's lysine recommendations; fast production rate, 1.5" die, 3% MAF

[4]Fisher's Least Significant Difference multiple comparison test value

[5]Standard Error of the Mean

Conclusions

Modern broilers respond positively to improvements in pellet quality. In addition, feed quality perception is enhanced with high quality pellets. Pellet quality can be improved using a variety of manufacture techniques. However, caution should be exercised when choosing manufacture techniques so that pellet quality improvement does not compromise nutrient availability. More research is necessary to elucidate specific techniques that will improve pellet quality without altering nutrient conformation to a degree where nutritional value is decreased. If the relationship between feed manufacture technique, pellet quality, nutrient availability, and performance is better clarified, then diet formulations will become more precise and cost effective at meeting nutrient requirements to maximize production and health of production animals.

References

Beaman, K.R., K.G.S. Lilly, C.K. Gehring, P.J. Turk, and J.S. Moritz. 2011. Determining efficacy of an exogenous enzyme cocktail post pelleting using broiler performance and metabolism. J. Appl. Poult. Res. In Press.

Briggs, J.L., D.E. Maier, B.A. Watkins, and K.C. Behnke. 1999. Effect of ingredients and processing parameters on pellet quality. Poult. Sci. 78:1464-1471.

Buchanan, N.P., and J.S. Moritz. 2009. Main effects and interactions of varying formulation protein, fiber, and moisture on feed manufacture and pellet quality. J. Appl. Poult. Res. 18:274-283.

Cutlip, S.E., J.M. Hott, N.P. Buchanan, A.L. Rack, J.D. Latshaw, and J.S. Moritz. 2008. The effect of steam conditioning practices on pellet quality and growing broiler nutritional value. J. Appl. Poult. Res. 17:241-269.

Fairchild, F., and D. Greer. 1999. Pelleting with precise mixer moisture control. Feed Int. 20:32-36.

Gehring, C.K., J. Jaczynski, and J.S. Moritz. 2009. Improvement of pellet quality with proteins recovered from whole fish using isoelectric solubilization-precipitation. J. Appl. Poult. Res. 18:418-431.

Gehring, C.K., K.G.S. Lilly, L.K. Worley, K.R. Beaman, S.A. Loop, and J.S. Moritz. 2011. Increasing mixer-added fat improves exogenous enzyme efficacy and broiler performance. J. Appl. Poult. Res. 20:75-89.

Hott, J.M., N.P. Buchanan, S.E. Cutlip, and J.S. Moritz. 2008. The effect of moisture addition with a mold inhibitor on pellet quality, feed manufacture, and broiler performance. J. Appl. Poult. Res. 17:262-271.

Lilly, K.G.S., C.K. Gehring, K.R. Beaman, P.J. Turk, M. Sperow, and J.S. Moritz. 2011. Examining the relationships between pellet quality, broiler performance, and bird sex
J. Appl. Poult. Res. 2011 20: 231-239.

Moritz, J.S. 2007. Impact of the pelleting process on dietary nutrients and supplemental enzymes. Pages 11–13 in Proc. Arkansas Nutr. Conf., Rogers, AR. The Poultry Federation of Arkansas (Little Rock, AR), Missouri (Jefferson City, MO), and Oklahoma (Oklahoma City, OK).

Reece, F.N., B.D. Lott, and J.W. Deaton. 1986. Effects of environmental temperature and corn particle size on response of broilers to pelleted feed. Poult. Sci. 65:636-41.

Reimer, L. 1992. Conditioning. Page 7 in Proc. Northern Crops Institute Feed Mill Management and Feed Manufacturing Technol. Short Course. p.7. California Pellet Mill Co. Crawfordsville, IN.

Wondra, K.J., J.D. Hancock, K.C. Behnke, R.H. Hines, and C.R. Stark. 1995. Effects of particle size and pelleting on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. J. of Anim. Sci. 73:757-763.