Feed Processing to Improve Poultry Performance

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Abstract

The recent record increase in ingredient markets has caused poultry companies to take a closer look at both their formulations and manufacturing processes. Poultry production companies no longer have access to low cost grain or energy sources, which affects the diet, manufacturing, and delivery cost of the feed. To remain competitive, poultry producers must focus on purchasing quality ingredients, manufacturing feed that optimizes profit, and delivering feed as economically as possible. Companies must also systematically evaluate each process within their production process starting with the purchase of ingredients to when the feed is delivered to the birds. This evaluation must be a coordinated effort between the ingredients purchasing agent, nutritionist, feed mill manager, and grow-out staff. The company must determine if a least cost diet yields the highest profit margin within their production system. Additionally, the company must evaluate the effect of particle size on nutrient utilization, the value of reducing the amount of fines in the feed, and the total cost of their feed delivery system. This paper will focus on the value of purchasing quality ingredients as well as manufacturing and delivering feed.

1 Introduction

Reducing the cost of production within a poultry company requires the commitment and involvement of all employees. A feed management team that is comprised of individuals from different areas of responsibility within a company can help identify potential savings and develop goals and objectives. Team members can also help communicate the company's vision to the other employees. The team must have a mission statement that clearly supports the company's mission, goals, and performance objectives. These objectives will vary based on the company's business philosophy. Regardless of the objectives they must be communicated to all employees involved in the production of feed and poultry. The first task of the team should be the creation of written procedures that focus on the team's goals and objectives. Written documents should include standard operating procedures, ingredient specifications, a quality assurance program, and preventive maintenance program. The second step is to implement these procedures and programs through employee training. The final step is to conduct follow-up audits to ensure compliance with the procedures and programs.

The two prevalent management strategies in the feed industry are to lower the cost of feed manufacturing within the feed mill or use the feed mill as a tool to optimize broiler performance and thus increase the profitability of the operation. Modern large scale feed mills have become extremely efficient and have few variable costs that can be further reduced in order to lower the total cost of the final feed. Although lowering manufacturing costs is important, companies should not lose sight of the fact that greater cost saving opportunities exist through the use of least cost formulation.

2 Ingredient purchasing and logistics

2.1 Alternative ingredient selection

The nutritionist, purchasing agent, and feed mill manager must work as a team to develop an ingredient purchasing strategy that can consistently supply safe high quality feed to their animals. Understanding the constraints or limitations of a feed mill prior to purchasing ingredients will limit an ingredient truck driver's wait time, railcar demurrage, unexpected formulation changes, and the potential negative impact that constant formula changes can have on bird performance as a result of the lack of ingredients. Communication with the feed mill manager, quality assurance laboratory, and grow-out team prior to the purchase of a new ingredient is essential to minimizing the hidden costs that could be associated with an ingredient change. The team members must recognize that alternative ingredients require added analytical costs in order to develop and maintain matrix values, increased receiving time at the mill, reduced batching times due to additional ingredients, and reduced pellet mill throughput. Additionally, alternative ingredients can change pellet quality, feed density, and palatability. Nutritionists should expect that these challenges will increase as the DDGS market begins to produce products with different levels of fat and protein.

Feed mills that have limited receiving pit capacity or ingredient storage capacity may not be able to consistently include alternative ingredients in all of their formulas. Some feed mills use rail cars as ingredient storage due to their limited bin capacity over their mixing system, which can create demurrage and increase the true cost of the ingredient. The team should also determine if variation in the diets due to the lack of ingredients will have a negative impact on feed consumption, growth rate, and feed conversion. These variations can be extreme especially when the formulas contain high inclusion levels of alternative ingredients. In cases where the mill's ingredient capacity is limited, the inclusion level of ingredients in formulas should be based on the level that will minimize the number of formula changes and provide the greatest profitability for the company.

2.2 Ingredient specification sheet

Ingredient specification sheets provide guidance to purchasing agents, suppliers, transporters, and receiving personnel and have always been the cornerstone of producing high quality finished feed, limiting product liability, and lowering the cost of feed (Stark and Jones, 2012). The use of approved suppliers and ingredient specifications sheets will likely become increasingly important as the FDA develops new regulations in response to the new Food Safety Modernization Act that was signed into law on January 4th of 2011 (FDA, 2011). Ingredient specification sheets should include: a product description, expected nutrient content, analytical methods, physical characteristics, and the basis for rejection.

2.3 Inbound ingredient logistics

Feed mills that have the ability to segregate and manage ingredients based on supplier and/or plant location can capture savings through least cost formulation if they can develop matrix values specific to a supplier or plant location. Simple inexpensive quality assurance tests at the point of receiving can help segregate ingredients based on moisture, protein, fat, and starch content. Equipment such as the grain moisture analyzer, NIR, or moisture balance can be used to rapidly determine the nutrient content of an ingredient prior to it receipt; typically these tests take less than ten minutes. Mycotoxins tests can also be conducted on ingredients prior to unloading if the feed mill suspects a problem based on previous shipments.

2.4 Ingredient variation

Ingredient variation exists due to differences in growing conditions, base raw material, and plant processes. The ingredient matrix nutrient values within the least cost program should be based on representative samples collected prior to or during the receiving process. Least cost ingredient matrix values should take into account both supplier and plant variation, ingredients with high variation will normally have a lower value within the least cost formulation program. A nutritionist can manage nutrient variation by applying safety margins to ingredients, which will adjust their estimated nutrient content based on the variation of the ingredient. Adjusting the mean nutrient value by one-half of its standard deviation is a common practice of nutritionists. DDGS is an alternative ingredient that tends to have more nutrient variation as compared to other by-products. Researchers have reported nutrient variation in samples of DDGS obtained from different ethanol plant in the Midwest (Batal and Dale, 2006, Belyea et al. 2010). Belyea et al. (2010) reported that fermentation batches within a plant had a greater effect on product variation than did plant or sampling period. The moisture content of an ingredient significantly changes the value of a product and ultimately affects its inclusion level in a least cost formula. The NRC for Poultry (NRC, 1994) reported the metabolizable energy (ME) content of corn as 3,470 kcal/kg at 11% moisture. However, most corn is delivered to feed mills between 13 and 15% moisture, which results in ME values of 3,392 and 3,314 kcal/kg, respectively. The change in moisture content of corn not only affects its value in the formulation but will influence the final moisture content of the feed delivered to the farm.

3 Feed manufacturing process

3.1 Grinding

Particle size reduction of cereal grains is a small fraction of the overall cost of feed manufacturing. The cost of grinding an ingredient is inversely related to particle size; the cost will increase as the target particle size is decreased. The cost of particle size reduction is dependent on the target particle size and the ingredient being ground. Preventive maintenance of the equipment is essential to achieving and maintaining the target particle size as well as lowering the operating cost of the process. Routinely replacing screens and hammers once the edges become worn will increase maintenance costs but will actually reduce the overall operating cost of the equipment. Anderson (2010) estimated that increasing the preventive maintenance cost of a hammermill by 2.5 times would result in a 24% reduction in total operating cost due to lower energy consumption per ton of ground material. The tendency of a feed mill manager is to reduce maintenance and labor costs by reducing the frequency of hammer and screen changes.

The average particle size of ground material is expressed as the geometric mean diameter (d_{gw}) of the sample as determined by the Method of Determining and Expressing Fineness of Feed Materials by Sieving (ASAE, 2009; ASAE S319.4). The standard method involves the analysis of the material utilizing 15 sieves and a Ro-tap® shaker. Although a standard method exists, researchers, laboratories, and feed mills may use modified methods, which can significantly change the results. The most recent change in the method is the inclusion of the statement, "For industrial applications, the end-point determination process can be omitted, and the end-point is set to be the sieving time of 15 min." Additionally, the use of sieving agents and agitators will reduce the estimated particle size result of the sample. Stark and Chewning (2012) reported that the addition of a sieve agent to hammermill ground corn reduced the estimated particle size of the sample from 411 to 332 microns, whereas the addition of the sieve agitators only resulted in a 41 micron decrease in particle size (392 versus 351 microns). However, the addition of both the sieve agent and agitator reduced the reported particle size from 443 to 323 microns. Feed mill managers should determine the average particle size of their ground grains on a routine basis.

Researchers have found limited improvement in feed conversion of poultry through a reduction in cereal grain particle size this is a contrast to the positive response shown in swine. The fact that poultry have a gizzard, which helps grind material before it passes through the GI tract has been proposed as a possible explanation for the difference in response. Several studies conducted with broilers and turkeys have not shown a benefit in performance when the particle of corn, wheat or soybean meal was reduced. Deaton et al. (1995) reported no difference in boilers fed corn ground through 3.18, 6.35, and 9.53 mm screens. Charbeneau and Roberson (2004) reported similar results in turkey poults fed corn that had been ground to 1094, 832, 701, and 606µm. Svihus et al. (2004) and Amerah et al. (2007) reported benefits in bird performance when a wheat based meal diet contained larger particles. Amerah et al. (2007) reported coarseness of grind did not affect growth rate or feed conversion within birds fed pellets. Chewning (2010) also reported the positive advantage of large particles in the meal feed tended to diminish when the diet is fed in the pellet form. Martinez and Parsons (2007) reported no advantage in phosphorus availability or bird performance by reducing the particle size of DDGS.

Recently, research at North Carolina State University has been focused on determining the optimal particle size and percentage of coarse corn required to promote the development of the pro-ventriculus and gizzard in order to improve digestion of ingredients and promote gut health. Particle size reduction has traditionally been used to increase the surface area on the grain particle (Goodband et al., 2002). However, a negative effect of reduced particle size has demonstrated with both extruded soybean meal and corn. Birds fed the finer particles had smaller gizzards relative to BW. Studies showed there is a correlation between the particle size of corn and gizzard development and feed utilization. Larger gizzards relative to BW have resulted in improved feed utilization (Xu, 2011) and gastric intestinal tract health (Ferket, 2010). Nir et al. (1994) stated that greater coarseness of feed increased relative gizzard weight while Amerah et al. (2008) suggested gizzard stimulation was due to the length of time that the coarse particles resided in the gizzard. Differences in research results may be influenced by whether the birds were raised in cage or floor pens as well as the quality of the litter within the pens. Birds that have access to litter may consume the litter in an effort to stimulate the gizzard when coarse particles of grains are not provided in the diet.

3.2 Batching

Reviewing production batch records daily is not only a requirement of the FDA's current Good Manufacturing Practices (cGMP's) it also makes business sense to insure birds are receiving the correct amount of nutrients and feed additives. Feed mill managers should monitor batch reports and look for trends in both shrink and gain of ingredients on a daily and weekly basis. Batches of feed that contain ingredients that were weighed to less than target (negative variance) will not provide the proper level of nutrients to the birds. Conversely, the addition of ingredients above the target weight can significantly increase the cost of the feed. The addition of two pounds of additional fat will add $1.00 to the cost of a batch of feed ($0.50/lb.). Depending on the size of the batch of feed the error could cost the feed mill between $0.10 and 0.20/ton of feed. Feed mill managers should also communicate to the nutritionist the resolution of their batch scales so that rounding factors can be applied to the least cost formula process. As an example, a formula that calls for 2.2 lbs. of a synthetic amino acid per ton and is weighed on a scale with a one pound resolution can only be weighed accurately when a five or ten ton batch of feed is manufactured, all other batch sizes will either add too much or too little synthetic amino acid to each batch of feed. Small differences between the amount listed on the master formula and the actual amount of ingredients weighed on the scales can create a significant inventory deviation over a one year time period.

3.3 Mixing

Ingredients should be added to the mixer starting with the discharge of the major scale followed by the minor and micro scales. The dry and wet mix time of the mixer should be established at the time of installation and then checked at least annually but preferably twice a year. The mixer should be tested using a single source ingredient in one batch of feed. Salt or synthetic amino acids are commonly used to test mixer uniformity. Ten samples should be obtained from the mixer by probing the mixer or collecting samples at equally spaced time intervals during the discharge process. The samples should be analyzed for the selected ingredient to determine the uniformity of the mix. The coefficient of variation (CV %) is determined by dividing the standard deviation of the samples by the mean and then multiplying by 100. The mix should have a CV% of less than 10%. McCoy et al. (1994) reported that a lower CV% (40 versus 10%) resulted in improved BW and feed conversion in chicks raised to 28 d of age. The feed mill should also have established sequencing and flushing procedures that minimize the cross contamination of medicated feed additives.

3.4 Pelleting

The pelleting process agglomerates ingredients that have different particle sizes, densities, and flowability. Pelleting allows nutritionists to formulate diets that include ingredients with poor flow characteristics which include grain ground to less than 400 microns without affecting the flow characteristics of the finished feed. The effectiveness of the pelleting process is measured by pellet quality as determined by the pellet durability index (PDI) and percent fines at the mill or in the pan in the house. Due to the fact that integrated poultry units do not remove fines and thus ship product that has both pellets and fines, the feed may contain from 20 to 60% fines when delivered to the birds.

The most common method used in the feed industry to determine pellet quality is the PDI (ASAE, 1997; S269.4), which was developed at Kansas State University. The method is often modified by adding hex nuts to create a more aggressive test, which is more representative of a company's manufacturing and delivery processes. Another method commonly used by the feed industry is the Holmen method, which uses air to create abrasion of the pellets versus the tumbling action that occurs in the metal box of the PDI tester. Regardless of what test is used the pellet quality test should be a predictive model of the manufacturing and handling processes that occur as feed is handled throughout the feed mill and delivery system. Each production system will have unique characteristics that must be taken into account when developing the model. Feed mills that develop a method to estimate pellet quality at the feeder can make the appropriate adjustments to processes within the mill to achieve the desired pellet quality. Additionally, the model can provide feedback to the nutritionist and purchasing agent as to the effect an ingredient or formulation change had on pellet quality.

Moritz et al. (2001), McKinney and Teeter (2004), Lemme et al. (2006), and Amerah et al. (2007) reported an improvement in feed conversion when birds were fed pellets versus mash feed. Greenwood et al. (2004) reported no difference in feed conversion in diets containing 20 to 60% fines. McKinney and Teeter (2004) indicated there was no advantage to producing more than 40% pellets unless pellet quality was in excess of 60%; the results of their study were used to develop an effective calorie value model. The model estimates the effects that pellet fines (0% to 80%) have on the caloric value of the diet. The model suggests an 80% change in fines results in a caloric difference of 111 ME/kg of diet, attributed primarily to a higher eating frequency associated with poor quality pellets. Hu et al. (2012) reported that birds fed crumbles in any quantity versus mash exhibited a higher feed intake, which resulted in a greater BW when fed in cages; however, most of the positive effect on BW that occurred from feeding high quality crumbles was no longer apparent at 35 d of age after the broilers were moved to the floor pens. The results were similar to those of Nir et al. (1995) who reported higher BW (2,298 g) with crumbled feed as compared to mash diets (2,236 g) at 35 d of age in male broilers. Additionally, Hu et al. (2012) demonstrated that 49 d old birds fed screened pellets (83% grower, 97% finisher pellets) versus pelleted feed that contained fines (46% grower, 51% finisher pellets) were 4.5% and 6.0% heavier in both males and females, respectively. These findings were similar to other researchers who reported the addition of fines to broiler diets reduced growth in all diet phases (Nir et al., 1995; Engberg et al., 2002; Svihus et al., 2004; Corzo et al., 2011). Amerah et al. (2007) suggested that these improvements could be attributed to increased nutrient density of the pellets, improved starch digestibility due to conditioning and pelleting the mash, increased nutrient intake due to the physical form of the feed, reduced feed wastage, and decreased energy expenditure during feeding (Amerah et al., 2007). Additionally, Buchanan et al. (2011) reported that diet formulation and manufacturing techniques affected broiler performance and intestinal morphology.

The cooling process is an important part of the manufacturing process that is often overlooked by feed mill managers. The goal of the cooling process should be to reduce the moisture content of the pelleted feed to the original or less than the original moisture of the mash feed prior to entering the conditioner. Residual moisture left in the pellets can lead to the growth of mold, degradation of pellets during handling, and dilution of the energy content of the feed (Stark, 2012). The energy content of a pelleted broiler diet that contains as little as 1% additional moisture after cooling will lower the calculated energy content of the diet, which will negatively affect feed conversion. Moisture levels greater than target are typically due to uneven bed depths in the cooler, the incorrect volume of air, or too many fines that block the air flow through the bed of pellets in the cooler. The speed of the cooler fan may need to be adjusted based on the ambient temperature of the air, which affects the water holding capacity of the air. Monitoring the mash before pelleting and the pellets after cooling will help the manager make the appropriate cooler and fan adjustments.

4 Feed delivery

The cost of feed delivery can increase significantly when trucks are not loaded to the legal weight limit (Table 1). The design and tare weight of the feed delivery equipment will determine the total weight of feed that can be hauled on a load. Selecting the correct type and design of equipment should be based on the condition of the roads, distance to farms, and operating philosophy of the company.

Table 1. Transportation cost based on tons delivered to a house.

	Tons Delivered per Truck			
Item	21	23	25	27
Variable Cost/Load, $	100	100	100	100
Delivery Cost, $/ton	4.76	4.35	4.00	3.70
Additional Cost, $/ton	1.06	0.64	0.30	0

5 Conclusion

Remaining competitive requires flexibility in both the feed mill and grow-out system. Poultry companies must develop a purchasing, manufacturing, and delivery model based on their organizational goals and objectives. The key to lowering feed costs is to understand the interrelationships that exist from the time ingredients are purchased to the time the bird consumes the feed. Feed mills vary in their design, cost structure, and manufacturing efficiency. However, the common denominator in feed mills should be a comprehensive quality assurance program that outlines the purchase of safe high quality ingredients, good manufacturing practices, and standard operating procedures that promote efficient and safe production of meat and eggs.

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