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RESEARCH OPINIONS IN ANIMAL & VETERINARY SCIENCES

Better feeding for better performance in broilers: A review

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Abstract

Feeding is a main part of poultry rearing programs. Normally, 70% of production cost is regarded as nutritional investments. To have an economically balance feed to reduce the costs, the main key issues that could be drawn into attentions are protein and amino acids, mycotoxins and feed processing and energy utilization. The importance of utilizing the correct amount of balanced dietary protein and amino acids for poultry is a high priority issue for several reasons. The costs of protein and amino acids are some of the most expensive nutrients in feeds/per unit weight. Selecting the correct level of amino acids needed for your company becomes a critical economic decision. Mycotoxins are produced by moulds and are very toxic for animals, plants and humans. The specific pathology caused and interference of metabolism is specific to the structure of the individual mycotoxin. Currently, approximately 300 different mycotoxins have been identified and data from ONU showed that mycotoxins are present in more than 30% of the cereal produced in the world. Energy utilization can be enhanced with hydrothermal processing of feed, leading to improvements in performance. Pelleting improves performance through physical characteristics of the pellet as well as the thermal modifications of the starch and protein. Improvements in turkey performance (growth, feed conversion and feed intake) have been observed although the response appears dependent on pellet quality. A large amount of metabolic energy is utilized causing additional body heat production in poultry during the process of eliminating excess nitrogen. The nitrogen not used in body gains or egg production must be converted into a non- toxic metabolite called uric acid and eliminated from the body. In this review, the emphasis on these key factors is discussed in details.

Keywords: Feeding; protein; amino acids; mycotoxins; energy; animal

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Introduction

Feeding programs have primarily emphasized live performance of meat birds taking into account effects on live weight or gain, feed conversion, and some times livability. In terms of connecting on-farm practices to processing and product marketing, nutrition plays an important role. Performance factors here could include condemnation losses and meat yield in particular breast meat due to its greater value. The degree of emphasis on feeding to obtain breast meat yield will be dependent on feed costs and product specifications. As greater breast meat deposition occurs with age (Moran et al., 1977; Peng et al., 1985; Swatland, 1989), feeding to heavier live weights with more nutrient dense diets may be necessary. The relationship of body weight and breast meat yield has been demonstrated (Douglas et al., 1999; Lilburn, 1999; Crouch et al., 2000). Body weight per se however may not accurately reflect breast meat yield for a number of reasons. Early influences on breast muscle development may not be detected. Influences on the growth curves and utilization of nutrients to produce meat as discussed later in this paper may not be apparent with body weight alone. In recent study on nutritional factors, which affect heavy tom performance such as protein, amino acids and energy, will be emphasized in this paper.

Protein and amino acids

Dietary crude protein (CP) requirements are somewhat of a misnomer as the requirement is based on the amino acids content of the protein. Once digested

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and absorbed, amino acids are used as the building blocks of structural proteins (muscle, skin, ligaments), metabolic proteins, enzymes and precursors of several body components. Because body proteins are constantly being synthesized and degraded, an adequate amino acid supply is critical to support growth or egg production. In poultry, 22 amino acids are needed to form body protein, some of which can be synthesized by the bird (non-essential), whereas others can not be made at all or in sufficient quantities to meet metabolic needs (essential). Essential amino acids must be supplied by the diet, and a sufficient amount of non-essential amino acids must also be supplied to prevent the conversion of essential amino acids into non-essential amino acid. Additionally, if the amino acids supplied are not in the proper, or ideal ratio in relation to the needs of the animal, then amino acids in excess of the least limiting amino acid will be deaminated and likely used as a source of energy rather than towards body protein synthesis. This breakdown of amino acids will also result in higher nitrogenous excretions. Essential amino acids must be supplied by the diet, and a sufficient amount of non-essential amino acids must also be supplied to prevent the conversion of essential amino acids into non-essential amino acid. Additionally, if the amino acids supplied are not in the proper, or ideal ratio in relation to the needs of the animal, then amino acids in excess of the least limiting amino acid will be deaminated and likely used as a source of energy rather than towards body protein synthesis. This breakdown of amino acids will also result in higher nitrogenous excretions. The best way to reduce N in poultry excreta is to lower the amount of CP that is fed by supplementing diets with amino acids. Reductions in the non-essential amino acid pool, coupled with supplying a more “ideal” amino acid profile in the diet can substantially increase the efficacy of overall N retention by the bird. On a practical basis, however, bird performance can be hindered by these lower CP diets due to a number of factors that tend to be associated with dietary CP and amino acid reductions.

Many studies have been able to demonstrate a relationship between breast meat yield (BMY) with that of diet protein. Waldroup et al. (1997a) found that large White toms increased percentage BMY as diets formulated to provide 85 to 120% of NRC (1994) recommendations for amino acids increased in protein content. Maximum BMY was obtained at 105% although the greater requirement over 100% NRC was thought to be due to higher environmental temperatures experienced during the trial. In a study originally presented by Stangeland et al. (1999), reductions in diet protein while maintaining essential amino acids other than threonine was associated with reductions in BMY (Table 1). Regression analyses indicated a higher requirement based on diet protein (thr) for BMY vs growth (96% vs 106% NRC threonine). Returns over feed cost were more affected by breast meat yield than live weight performance (Table 2). In a study on diet protein and threonine supplementation, Kidd et al. (1997) concluded that diet protein could be decreased to 92% of NRC (1994) with supplementation of lys, met (TSAA), thr and trp to 105% NRC (1994) to obtain BMY similar to control while diet protein could be reduced to 84% with additional threonine and still have favorable growth and feed conversion. Sell (1993) found that feeding a reduced diet protein series (93% NRC 1984) supplemented with lysine and methionine resulted in decreased BMY but with no effect on weight or feed conversion in one of two studies. However, in a number of other studies breast meat yield was not affected by protein level and did not interact with diet metabolizable energy level (Sell et al., 1985; Sell et al., 1989; Sell et al., 1994).

Requirements for individual amino acids have been shown to be greater for breast meat yield and feed efficiency as compared to requirements for breast meat. In broilers, Schutte and Pack (1995) found the TSAA requirement for growing broilers was 0.05% greater for BMY and feed conversion in comparison to that for growth. Han and Baker (1994) also found a higher lysine requirement for broiler BMY and FG in comparison to that for body weight. In a study examining the threonine requirement of male turkeys approximately 0.06% more threonine was required for BMY vs body weight (Lehmann et al., 1997). Lehmann et al. (1996) also indicated a response to lysine for male turkeys during 16-20 wks of age in excess of NRC (1994) (0.8% vs 0.96%) for growth and breast meat yield. Waibel et al. (1995) supplemented 100% NRC protein diets with an additional 10% methionine and obtained a breast meat response in one of two studies with market turkeys. Interest continues in utilizing diets of reduced protein supplemented with critical amino acids. Reductions in dietary protein are sometimes desired due to cost of protein ingredients. Pressure also exists to reduce nitrogen excretion to the environment and this may be achieved by lowering diet protein and utilizing supplemental amino acids. Can this be done without sacrificing meat yield? Research studies with turkeys indicated that protein could be reduced to 85% of NRC (with supplemental met and lys) and still achieve growth near that of the control protein series of 100% NRC (Waibel et al., 1995, 2000a and 2000b). However when breast meat yield was examined, reductions in protein resulted in equivalent growing performance but reduced breast meat yield.

Amino acid balance may also compromise breast meat yield. Combinations of alternative ingredients or utilization of products with poor amino acid balance may lead to decreased BMY.

Table 1: Protein (threonine) level and tom turkey performance (8 to 20 wks)[1]

Diet[2,3]	Body weight	Feed/Gain	Breast Meat Yield[4]	
			Amount	Carcass
	(lbs)		(lbs)	(%)
prot) 108% NRC	39.4[ab]	2.88[cd]	9.33[a]	30.2[a]
prot) 100% NRC	39.6[a]	2.84[d]	9.22[a]	29.7[b]
prot) 92% NRC	38.8[b]	2.88[cd]	8.67[b]	28.8[c]
prot) 84% NRC	37.7[c]	2.98[b]	8.23[c]	27.9[d]
prot) 78% NRC	37.3[c]	2.94[bc]	8.21[c]	28.4[cd]
prot) 70% NRC	35.3[d]	3.08[a]	7.92[c]	28.4[cd]

[1]From: Stangeland et al. (1999); [2]All diets supplemented with lys, met, arg, try; [3]Diets 5 and 6 supplemented with iso and val; [4]Breast meat only (without skin and bone) and as percent of chilled carcass weight

Table 2: Protein level and economic analyses[1]

NRC Threonine Protein)	108% Thr	100% Thr	92% Thr
Live wt (lbs)	39.4	39.6	38.8
F/G 8-20 wks	2.88	2.84	2.88
F/G 0-20 wks (estimated)	2.53	2.50	2.51
Feed $/lb LW[2]	.160	.157	.156
Feed $/tom	6.33	6.22	6.03
Return $/tom[3]	7.48	7.67	7.54
Breast Meat (lb)/tom	9.33	9.22	8.69
Feed $/ lb breast meat	.677	.673	.694
Return $/tom[4]	4.89	4.86	4.37

[1]Adapted from Stangeland et al. (1999); [2]Ingredient cost plus $12/ton overhead; No LW or F/G adjustment for mortality or condemnation; [3]Revenue $.35/lb LW; Return over feed cost only; [4]Revenue $1.20/lb breast meat; Return over feed cost only

Waldroup et al. (1993, 1998) restricted amino acid intakes of male turkeys to 75% of NRC during the following age periods of 0-3, 0-6 or 6-12 wks of age. Restriction in this case did decrease weights at 18 wks with corresponding decreases in BMY. BMY was most reduced in birds restricted for 6 wk regardless of early restriction or restriction during growing. Hester et al. (1990) also restricted turkeys to 12 wks of age and followed by feeding of a low or high plane of nutrition. While weights equivalent to the control were obtained, BMY was decreased. Authors commented that during the re-feeding period, growth occurred in the thigh muscle instead of breast muscle. Waldroup and co-workers found breast meat yields were reduced when the feeding schedule was advanced too quickly in turkeys (Waldroup et al., 1997b). In this study, diets with 100% NRC amino acids were adequate when fed at 4 wk intervals. When the same diet series was switched to 3 wk intervals, BMY was reduced. Besides dietary protein, breast meat yield may be affected through other mechanisms. As indicated in a companion paper in this proceedings (Noll et al., 2002), betaine may be able to enhance deposition of meat through a variety of mechanisms. In another study, the addition of betaine improved yield amount and as a percent of carcass weight in heavy toms in both winter toms (Kalbfleisch et al., 2000) and under summer rearing conditions. The response was consistent despite differences in final market weight (Table 4).

Mycotoxins

Mycotoxins are produced by moulds and are very toxic for animals, plants and humans. The specific pathology caused and interference of metabolism is specific to the structure of the individual mycotoxin. Currently, approximately 300 different mycotoxins have been identified and data from ONU showed that mycotoxins are present in more than 30% of the cereal produced in the world.

The important challenge when evaluating mycotoxin problems is that it is not easy to detect the presence of mycotoxins in animal feed that elicit impaired performance or mycotoxin diseases. Inadequate feed sampling is the most common factor determining variability in mycotoxin analysis. Mycotoxins are not evenly distributed throughout a feed/food batch; they are more concentrated in areas with higher humidity and/or with higher oxygen levels. Hence, in the majority of cases, feed samples are taken from only one small section of the container or batch which is not representative of the entire batch. In such instances, the mycotoxin analysis could be negative or be higher positively depending upon where the sample was taken from. Additionally, in most commercial situations when mycotoxicoses is observed or suspected, the animals have already eaten all of the feed with no samples left for analysis. Furthermore, in field situations, more than one mycotoxin is normally present in the feed, and as analysis is normally for the presence of one particular indicator mycotoxin, the analysis can

Table 3: Inclusion of alternative ingredients (canola meal and distillers grains with solubles – DDGS) in market turkey diets and effect on live performance (5-20 wks of age) and breast meat yield at 19 wks[1]

Dietary Treatment	Body weight at 19 wks (lbs)	F/G 5-19 wks	Breast Meat Yield[2] (%)
1. Corn-soy-meat	41.6	2.44	30.74[a]
2. As 1 plus DDGS	41.9	2.48	30.45[ab]
3. As 1 plus canola	42.2	2.47	30.88[a]
4. As 1 plus DDGs and canola	41.8	2.47	29.93[b]
5. As 4 plus trp	41.9	2.49	30.43[ab]
6. As 5 plus iso	41.7	2.45	29.98[b]
7. As 6 plus arg	42.2	2.47	30.78[a]

[1]From Noll et al. (2002); response averaged over cool and warm temperature environments; [2]Breast meat only (without skin and bone) and as percent of chilled carcass weight

yield lower levels of mycotoxins. Mycotoxins work in synergy together to elicit their detrimental effects; hence a low result for one mycotoxin can be misleading.

Fungi growth can occur in different phases of plant and animal production. For example, they can invade the seeds before harvest while the crop is still in the field, or they can grow during storage at the feed mill or the farm. They can also grow during feed processing, for example when the mixer increases the temperature and humidity of the feed. Additionally fungal growth and mycotoxin problems could also occur in the feeders when they are not adequately clean.

In reality, the losses resultant from fungal growth can be due to physical injury of the grain, losses in nutritional quality of the grains and the production of toxins by the fungi. The fungi metabolic activity is associated with aerobic respiration so, the grain deterioration is a reaction of the oxidation of fat and carbohydrates in the presence of oxygen, resulting in carbonic acid, water, heat and fungal structure. Some of the important mycotoxins are aflatoxins, Ochratoxin A, T-2 toxin, rubratoxin B and citrin. Aflatoxin B_1 is most pathogenic to poultry as compared to other aflatoxins *viz.* B_2, G_1 and G_2. Aflatoxin toxicity (aflatoxicosis) has been reported to cause serious health hazard to poultry and other avian species. Aflatoxicosis in chicken is characterized by listlessness, anorexia, poor pigmentation, jaundice and dehydration of combs and shanks. Sensitivity or resistance to aflatoxins is inherited as distinctive characteristics of breed and strain. The adverse effect of aflatoxins on performance of chicken is also dose and time related. This toxin is primarily a hepatotoxin in young broiler chicken. One effect that is used as a diagnosis of aflatoxicosis in poultry is an enlarged, fatty, yellow and friable liver that occurs in broilers when they consume aflatoxins contaminated feed. This mycotoxin is also a nephrotoxin and some kidney pathology does results during aflatoxicosis. Aflatoxins affect the commercial poultry production in many ways: (a) reduce body weight gain; (b) make birds more susceptible to brushing; (c) decrease egg production, egg weight and hatchability; (d) suppress the immune system of poultry making them more susceptible to diseases; (e) disrupt bone development causing a rachitic type problem and (f) can cause nutritional problems through its effect on nutrient absorption and metabolism (Manafi et a.,l 2012). Aflatoxin inhibits fat digestion with a consequent streatorrhoea by decreasing enzymes and bile acids resulting into high faecal fat and liver fat content. Aflatoxin causes reduction in nutrient retention, changes in haematological values and bio-chemical parameters. This toxin causes low or heavy mortality depending upon level and duration of intake of contaminated feed. Reduction in size of bursa of Fabricious is observed in growing chicks during aflatoxicosis. Ochratoxin A is primarily a nephrotoxin in poultry but it does have some secondary hepatotoxicity. The major diagnostic lesion of this mycotoxin is pale and enlarged kidneys. Ochratoxin like aflatoxin can affect poultry in number of ways: it i) depresses growth of poultry; ii) acts as an immuno-suppressant making birds more susceptible to diseases and brushing and iii) can affect nutrient absorption and metabolism. It is important to note that ochratoxin is three times more toxic than aflatoxins to broiler chicken. This toxin is produced by certain Pencillium (*P. Verrucosum*) and Aspergillus (*A. Ochraceus* and *A. alutaceus*) species. It has been implicated in total human disease Balkan Endemic Nephropathy. T-2 toxin is produced by fungus *Fusarium tricincutum*. T-2 toxin is another mycotoxin that can produce severe adverse effects on broiler chicken. T-2 toxin is a radiomimetic toxin, which means that the toxicity of T-2 toxin is very similar to the effects of radiation. The principle presumptive lesion caused by T-2 toxin is a crusty lesion in the mouth of poultry on lower and upper mandible. T-2 toxin can limit poultry production by a number of methods: 1) decreasing body weight 2) acting as immuno-suppressant and 3) altering nutrient

Table 4: Betaine addition to tom turkey diets (5-20 wks)[1]

Trial	No betaine	Betaine[2]
Study 1 (Winter)		
Body weight (lbs)	43.7	44.0
Breast meat yield (%)[3]	32.7b	33.6a
Breast meat (lb/tom)[3]	11.2b	11.6a
Study 2 (Summer)		
Body weight (lbs)	40.1	40.3
Breast meat yield (%)[3]	30.0b	30.8a
Breast meat (lb/tom)[3]	9.5b	9.9a

[1]From: Kalbfleisch et al. (2000); Noll et al. (2002); [2]As Betafin S1 (2 lbs/ton); [3]Breast meat (without skin and bone) and as percent of chilled carcass weight

Table 5: Feed processing and dietary energy amino acid ratio effect on turkey performance and carcass characteristics[1]

Treatment description	Body weight at 138 days	Feed/Gain 35 to 138 days	Breast meat Yield	
	(lb)		(lb)	(%)
Mash–108% NRC ME	41.0[a]	2.42[c]	10.21[ab]	31.45[b]
Mash–104% NRC ME	39.8[b]	2.52[b]	9.96[b]	31.85[b]
Mash–100% NRC ME	39.8[b]	2.68[a]	9.96[b]	31.81[b]
Mash Average	40.2[B]	2.54[B]	10.05[B]	31.70[B]
Crum–108% NRC ME	41.8[b]	2.33[d]	10.78[a]	32.01[ab]
Crum–104% NRC ME	41.7[b]	2.40[c]	10.58[a]	32.00[ab]
Crum–100% NRC ME	41.7[b]	2.53[b]	10.83[a]	33.00[a]
Crumble Average	41.7[A]	2.42[A]	10.74[A]	32.34[A]

[AB] Means of mash and crumble feed are significantly different (P<.05); [1]From: Stangeland et al. (1999)

absorption and causing nutritional disease (Manafi et al., 2011). Dietary additives and their dietary inclusion levels for protection to broilers against dietary aflatoxins are extensively shown in Table 6.

Feed processing and energy utilization

Energy utilization can be enhanced with hydrothermal processing of feed, leading to improvements in performance (Behnke, 1996). Pelleting improves performance through physical characteristics of the pellet as well as the thermal modifications of the starch and protein. Improvements in turkey performance (growth, feed conversion and feed intake) have been observed although the response appears dependent on pellet quality.

Expanders have been used to improve pellet quality and output. An improvement in broiler performance was obtained with expander use. Fancher et al. (1996) compared expanded conditioning with conventional conditioning followed by pelleting of broiler feeds. Growth and feed conversion were improved by 4.7% and 3.9%, respectively, for the expanded feed.

Table 6: Dietary additives and their dietary inclusion levels for protection to broilers against dietary aflatoxins

Detoxifying agents	g/qtl. Feed
Activated charcoal	100 - 200
Hydrated sodium calcium aluminosilicate (HSCAS)	100 - 200
Esterified glucomannan (EGM)	50 - 100
Herbal mixture (*Acacia catechu. 25%, Phyllanthus niruri*, 400%, Andrographis paniculata, 25%, base 10%)	50 - 75
Butylated hydroxyanisole	50 - 100
Dl-methionine*	100 - 200
Selenium**	0.200 - 0.300
Butylated hydroxy toluene*	50 -150
L-lysine HCI	150
Water soluble vitamins*	Double of the requirements
Increase the dietary protein level	Upto 26 to 28%

*Growth sparing effect; **Alleviation of toxicity due to low levels of aflatoxins; growth and mortality effects at higher levels of aflatoxins.

Therefore, pelleting the diet, adjusting protein to energy ratio and modifying nutrient density are methods that can be used to affect feed and amino acid intake leading to more body weight gain and meat yield. In the study reported by Stangeland et al. (1999), turkey toms were reared under winter season conditions and fed diets formulated to three energy levels of 108% NRC, 104% NRC, and 100% NRC with dietary amino acid concentration for lysine, TSAA, and thr held constant at each energy level. Each diet was fed as a mash and as expanded/crumbles. Lysine and TSAA levels were set at 108% of NRC requirement. Thr was at 100% of NRC. Body weights on the crumble diets were significantly greater than on mash diets at each weighing (Table 5). Raising the energy level of the crumble diets had little effect on rate of gain. Whereas, the toms on the 108% NRC ME mash diets gained significantly more than those fed mash diets with lower energy levels. Large differences in feed conversion were observed among feed form and energy level. The carcass yield data shows that breast meat yield was significantly greater on crumbles than from toms fed mash feeds.

In summary, a number of reported research trials indicate that breast meat yield is responsive to protein and amino acid levels above that required for growth. Balance of amino acids was also shown to affect breast meat yield to a greater extent than growth. Greater growth and breast meat yield was obtained with pelleted diets. Depending on feed costs, growth and breast meat yield can be obtained with a variety of strategies.

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