

*Review Article***Nutritional Interventions to Improve Breast Meat Yield in Broilers – Review****P. Kanagaraju*, S. Rathnapraba¹, R. Richard Churchil, N. Madhan Kumar and Survase Swapnil**

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Abstract

Broilers are mainly reared for meat purpose throughout the world and the industry now focusing mainly toward processing. Hence, much of the selection pressure is applied to improve the growth rate and carcass yield, with a significant increase in breast muscle. The increasing demand for white meat and the continuous improvement in genetic potential of commercial broiler lines has resulted in important changes in the nutritional management of broilers. Numerous factors affecting breast meat and it can be broadly divided into nutritional and non-nutritional. Among non-nutritional factors genetic factors, management including feeding and lighting management affect breast meat yield. Nutritional factors such as protein: energy ratio, amino acids particularly threonine, arginine, methionine, lysine and total sulphur containing amino acids are playing a major role. Apart from this, amino acid interactions such as dietary Lysine X Methionine and Lysine X Threonine are important to optimize meat accretion particularly breast region. Betaine along with methionine increased breast meat yield in broilers than when they fed alone. Chelated trace mineral improves breast meat yield due to improved general bird health and greater bioavailability, resulting in fewer nutrients being directed to immune function and more being available for muscle deposition. Pellet and crumbles are having a positive effect on breast meat yield in broilers. Information regarding factors affecting breast meat yield in broiler production can improve the quality of broiler.

Key words: Amino Acids, Broilers, Breast Meat Yield, Energy Protein Ratio, Nutritional Factors**How to cite:** Kanagaraju, P., Rathnapraba, S., Churchil, R., Madhan Kumar, N., & Swapnil, S. (2019). Nutritional Interventions to Improve Breast Meat Yield in Broilers – Review. International Journal of Livestock Research, 9(8), 49-61. doi: 10.5455/ijlr.20170911084640**Introduction**

Tremendous improvement in commercial broiler performance has taken place since the 1950s. This improvement was possible by selection for rapid early growth, combined with improved environment, management of broilers, such as nutrition and housing (Narahari and Kumararaj, 2008). Due to

modernization of poultry production practices, the feed conversion ratio in broilers has improved from 2.5 to 1.6. Also, the body weight which was achieved at eight weeks of age during the eighties is now realized in 35 days of age (Kanagaraju, 2014).

A great proportion of broilers raised in the poultry industry are destined towards the further processing markets. The change in the poultry market toward processing has been strongly related to the improvement in poultry growth and carcass yield, with a significant increase in breast muscle proportion. The change in the poultry market toward processing has been strongly related to the improvement in poultry growth and carcass yield, with a significant increase in breast muscle proportion (Wang *et al.*, 2012). A priority to some integrators is the maximization of skinless-boneless breast meat yield, which in turn has encouraged optimizing strategies to improve this particular parameter in an economically feasible way through nutritional and non-nutritional interventions. Many efforts were taken to improve breast meat yield, factors affecting its development and accretion rate, with particular emphasis on nutrition.

Nutritional management has become an integral part of poultry production. The increasing demand for white meat and the continuous improvements in the genetic potential of commercial lines have resulted in important changes in the nutritional management of broilers. During recent years, it has become a common practice to grow broilers under high protein diets in an attempt to maximize growth with a proportionate increase in the breast meat. Further males are reared separately from females, and also beyond 8 wk of age to obtain large quantities of breast meat. Breast meat is the most valuable portion for North American commercial broiler producers, and greater breast meat yields translate into increased profits.

Factors Associated with Breast Meat Yield Variation

Associated improvements of breast meat yield are not clearly understood physiologically. The explanation may likely to revolve around myofibre quantity or size. Myofibre types and cross-sectional areas of broilers with lower yield recorded by Remington *et al.* (1996) and Scheuermann *et al.* (2003). There may be an exacerbation of glycolytic activities in breast muscle of high-yield broilers. However, there appear to be no changes in pH, colour and drip loss with increased breast meat yield (Young *et al.*, 2001). Female broilers were have been reported to have lower myofibre density than males (Scheuermann *et al.*, 2003). Myostatin, a growth factor known to negatively regulate muscle mass (Lee and McPherron, 2001), appears not to be differentially expressed when comparing breast muscles of high breast meat yield broiler and commercial leghorn (Scheuermann *et al.*, 2004). The factors affecting breast meat can be classified into nutritional and non-nutritional factors.

Non-Nutritional Factors Influencing Breast Meat Yield

Primary broiler breeder companies, through genetic selection, have offered a modern broiler with extraordinary white meat yielding capabilities. Population geneticists have taken full advantage of the

heritability of rapid growth broilers, estimated to be approximately 0.53 and 0.65 for breast meat weight and yield, respectively (Bihan-Duval *et al.*, 1998). Differences in breast meat yield as a result of genetic selection based on different production parameters i.e. growths vs. breast meat yield have been observed by Moran *et al.* (1993).

Further, management practices are also likely to influence breast meat yield values as certain feeding programs may result in an increased tendency towards the development of sudden death syndrome, ascites and leg problems (Madrigal *et al.*, 1994), which in turn may adversely affect breast muscle development and livability per se. Reduced lighting early in life found to reduce leg-related problems may reduce breast meat yield even though body weight and feed conversion recorded to be satisfactory (Renden *et al.*, 1993). High environmental temperature found to reduce muscle accretion. The muscle most susceptible to elevated temperatures is the Pectoralis (Howlider and Rose, 1989; Smith, 1993). This might be due to a reduction in protein synthesis (Muscle RNA/protein) in breast muscles (Temim *et al.*, 2000). Ultimately, broilers exposed to high environmental temperatures have a more prominent reduction in protein synthesis when compared to breakdown, resulting in decreased breast meat yield.

Genetic Makeup of Broilers

The increasing market demands for white meat has compelled poultry breeders to focus selection for a high percentage of breast meat (Brake *et al.*, 1993; Pollock, 1997), resulting in chicken with a higher portion of the breast. The heavier body weight of contemporary broiler chicken also explains the higher relative yield of the breast, because heavier birds produce a greater portion of the breast (Marks, 1995; Moran, 1995). Body and breast muscle weights appeared to be significantly related to fiber size, with positive genetic correlations of 0.69 ± 0.08 , 0.76 ± 0.06 and 0.48 ± 0.09 between muscle fiber and weight gain (between 4 and 6 weeks), breast muscle yield and breast muscle fibre, respectively (Elisabeth Le Bihan-Duval, 2008). Interestingly, breast muscle weight exhibited a significantly negative genetic relationship with muscle glycol protein ($rg -0.58 \pm 0.11$), and in turn a positive correlation with pH (0.84 ± 0.07). Significantly negative genetic correlations were also found between breast muscle mass and lightness ($rg -0.55 \pm 0.10$), drip loss (-0.65 ± 0.10), thawing-cooking loss (-0.80 ± 0.06) and Warner Bratzler shear force (-0.60 ± 0.10).

Nutritional Interventions to Improve Breast Meat Yield

Breast meat of broilers has minimal fat deposits, largely due to the metabolism of its muscle fibres which relies mostly on glycolytic activities, whereas dark meat such as thighs, possess an oxidative metabolism by nature and larger fat deposits. Therefore, it is reasonable to assume that maintenance needs of breast

muscles may vary from other muscles. While variation in the composition of breast meat is minimal, its yield may be more sensitive to outside factors, particularly nutrition.

Metabolizable Energy

Leeson *et al.* (1996) determined that providing broilers with suboptimal caloric density from 35 to 49 d did not affect final BW and meat yield, because birds were able to compensate by adjusting feed intake. But feed conversion was adversely affected. Dozier *et al.* (2006) evaluated diets varying in Apparent Metabolizable Energy (AME) content fed to Ross × Ross 308 broilers from 1.5 to 3.9 kg. Increasing AME from 3,220 to 3,310 kcal/kg decreased feed consumption and improved feed conversion by 8 points in broilers subjected to low temperatures but limited breast meat yield.

Crude Protein

Leeson *et al.* (1996) and Dozier *et al.* (2006) determined that increasing crude protein, lysine and total sulphur containing amino acids (TSAA) concentrations by 4% in a diet formulated to contain 3,310 kcal/kg of AME ameliorated the negative response of breast meat yield associated with decreased amino acid (AA) intake of a high AME diet (3,310 kcal of AME/kg) under moderate temperatures (24°C). McNaughton and Reece (1984) also demonstrated that increasing the Lysine content to 1.05% (total basis) with diets containing to 3,250 kcal of AME/kg increased body weight (BW) gain when 2.0-kg broilers were exposed to a moderate temperature (26.7°C), but the response for dietary AME was decreased to 3,100 kcal of AME/kg as dietary lysine was decreased to 0.96%.

Many studies demonstrated a relationship between breast meat yield (BMV) and dietary protein. Waldroup *et al.* (1997a) found that in large white toms increased BMV with diets formulated to provide 85 to 120% of NRC (1994) recommendations of amino acids content. Maximum BMV was obtained at 105% although the greater requirement over 100% NRC was thought to be due to higher environmental temperatures experienced during the trial. Stangeland *et al.* (1999) observed a reduction in diet protein while maintaining essential amino acids other than threonine was associated with a reduction in BMV. Regression analyses indicated a higher requirement based on diet threonine (96% vs 106% NRC) for BMV vs growth. In a study on diet protein and threonine (Thr) supplementation, Kidd *et al.* (1997) concluded that diet protein could be decreased to 92% of NRC (1994) with supplementation of lysine, methionine, threonine and tryptophan (TSAA) to 105% NRC (1994) to obtain BMV 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 BMV 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).

Amino Acids

Breast muscle contains a high concentration of lysine in both broilers and turkeys. Lysine, being second limiting amino acid in a typical broiler diet, considered pivotal if maximization of breast yield is desired. It has been well documented how lysine supplementation above recommended level increases breast meat yield (Hickling *et al.*, 1990; Kidd *et al.*, 1998). It was also observed that increased supplementation (above NRC 1994) resulted in a vast increase in breast meat yield. 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 alone. Schutte and Pack (1995) found that 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 fillet growth 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) (0.80% 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.

Dietary methionine is also known to greatly impact breast meat yield (Kalinowski *et al.*, 2003). As it is the first limiting amino acid in broiler diet makes methionine just as important as lysine for muscle accretion. Lack of dietary methionine supplementation for breast tissue deposition eventually affected its yield, and subsequent supplementation may alleviate any deficiency effects. Amino acids are critical for muscle development (Tesseraud *et al.*, 1996) and lysine content in breast muscle is relatively higher than other AA. Lysine represents approximately 7% of the protein in breast meat (Pectoralis major and minor muscles). Dietary lysine inadequacy found to reduce breast meat yield compared with other muscles (Tesseraud *et al.*, 1996). Therefore, defining dietary AA need for optimum growth and meat yield is of utmost importance.

In a recent study, De leon (2006) determined the lysine requirement for 15 to 35-day old Ross × Ross 708 broilers as 1.17% (1.04% digestible lysine) for optimum breast meat yield. From 6 to 8 wk, Corzo *et al.* (2006) reported the dietary lysine requirement as 0.93% for breast meat yield with male Ross × Hubbard broilers. Female broilers did not respond to increasing dietary lysine for growth and meat yield parameters. Although feeding high lysine diets throughout production optimizes breast meat yield (Kidd *et al.*, 1998). However, evidence in the literature suggests that feeding a diet high in lysine during the starter period impacts subsequent breast meat yield at marketing age (Kerr *et al.*, 1999). Kidd *et al.* (1998) evaluated

various lysine concentrations in starter, grower, and finisher periods during a 49-d production cycle. Feeding broilers, a diet with 1.25% lysine from 1 to 18 d produced a 1.1% higher breast meat yield compared with broilers fed 1.04 %. Broilers fed the 1.04 % dietary lysine during the starter period and provided 1.05 or 1.25% from 19 to 49 d of age did not respond with similar breast meat yield compared with broilers consumed 1.25% throughout 49 days production period.

The third limiting amino acid threonine has also been shown to be critical for breast meat yield improvement (Kidd *et al.*, 2004). Dietary threonine needed by male broilers in heat stress environment was estimated to be 0.67% between 42 to 56 days of age in order to optimize feed conversion. Breast fillets deboned from the carcass were the only carcass part improved by threonine and a total of 0.62% was necessary for maximum yield. Iso leucine is typically next limiting amino acid, also found to affect breast meat yield responses (Kidd *et al.*, 2004) as this is critical for breast meat accretion. The high demand for amino acids by breast muscles may be exacerbated due to the high protein synthesis and turnover activity exhibited in these muscles (Urdaneta- Rincon and Leeson, 2004). Kidds *et al.* (2004) fed various amino acid density levels to Ross 508 males and females from placement up to 49 days. Live performance of these broilers showed that males responded to increased amino acid density in greater proportion than females, suggesting a potential for separate rearing if male and female diets are fed. Dozier *et al.* (2006) evaluated dietary amino acid responses from 36 to 59 d of age. Cumulative feed conversion and total breast meat yield were adversely affected as dietary amino acid density was decreased from high-high to low-low diets during 36 to 59 days of age.

Role of Amino Acids in Muscle Development

Postnatal protein accretion results from an increase in protein synthesis or a decrease in protein degradation. Diets containing low lysine can limit breast meat formation early in development by reducing protein accretion from protein synthesis and RNA content (Tesseraud *et al.*, 1996, 1992). Dietary protein has been shown to regulate insulin-like growth factor 1 (IGF-I) concentrations (Tesseraud *et al.*, 2003) in avian species. Doumit *et al.* (1993) reported that IGF-I stimulates differentiation and proliferation of satellite cells. They also found that a 62% increase in protein synthesis and a 38% decrease in protein degradation when muscle cells were incubated with IGF-I. The expression of transcription factors c-fos are activated by IGF-I (Florini *et al.*, 1996), and c fos transcription factor binds to another transcription factor, c-jun, to form a complex known as AP-1 protein. The AP-1 protein activates transcription of myogenic genes. The activation of transcription by IGF-I has also been reported by Ong *et al.* (1987) who reported a 4-fold increase in mRNA of skeletal muscle cells when incubated with IGF-I. Muscle DNA accumulates as myofiber size increases during postnatal growth, even though myofiber numbers are fixed and myonuclei

do not divide. Providing broilers an amino acid (HAA) dense diet increases breast meat yield, likely by increasing myofiber size via modulating protein synthesis and protein degradation.

Amino Acid Interactions

Feeding high lysine and AA dense diet to broilers increase breast meat yield (Dozier *et al.*, 2007). Dietary AA influencing breast meat yield may be additive among AA (Hickling *et al.*, 1990; Kerr, 1999), but found no interactions between lysine and methionine (Kersey *et al.*, 2004). Hickling *et al.* (1990) reported that broilers fed diets with increasing lysine concentrations from 100 to 112% NRC recommendation needed a dietary methionine concentration at 112% (NRC) to optimize carcass and breast meat yields. Dietary lysine and threonine concentrations have also been shown to interact to optimize meat yield (Kerr *et al.*, 1997). Dietary lysine \times methionine and lysine \times threonine interactions were apparent to optimize meat accretion. Increasing dietary lysine without an increase in methionine and threonine may limit protein synthesis, hence not allowing for maximum meat accretion.

Betaine

Besides a possible methionine sparing effect, betaine may also interact with the lipid metabolism by stimulating the oxidative catabolism of fatty acids via its role in the carnithine synthesis, thus offering a potential for reduced carcass fatness in commercial production. Betaine has been indicated to have a number of a metabolic and physiological role in poultry nutrition (Kidd *et al.*, 1997; Remus, 1998). Betaine as a methyl group donor could spare either choline or methionine. Simon (1999) has indicated that betaine may have the greatest effect as an osmolyte especially under coccidial challenge. Enhancing lean meat deposition by decreasing carcass fatness through its effect on lipid metabolism is another proposed role for betaine (Saunderson and MacKinlay, 1990). Rostagno and Pack (1996) noted no response to betaine in a broiler study. Betaine (0.1%) alone had no effect while betaine plus .06% methionine increased breast meat yield slightly. Schutte *et al.* (1997) supplemented methionine deficient diets with DL-methionine (0.05, 0.1%) and betaine (0.04%). Betaine alone increased breast meat yield but not to the same extent as 0.05% methionine. An interaction of methionine and betaine for breast meat mass was noted by McDevitt *et al.* (2000) in broilers where betaine did not improve breast meat mass in the basal diet.

Effects of Chelated Trace Minerals on Growth Performance and Breast Meat Yield

The bioavailability of chelated trace minerals (CTM) is more than inorganic trace mineral (ITM), chelated trace minerals (CTM) due to reduced antagonistic reactions with other dietary constituents in the gastrointestinal tract. Greater bioavailability can translate into numerous benefits to birds, including improvements in tissue development and integrity, enhanced immune function and growth performance (Dibner, 2006). He observed that CTM improved breast meat yield in males [22.38% for ITM (control) and

22.99% for CTM; $P = 0.09$] and percentage of tenders in both males (3.77 vs. 3.92%; $P = 0.02$). These benefits are perhaps due to improved general bird health and greater CTM bioavailability, resulting in fewer nutrients being directed to immune function and more being available for muscle deposition.

Form of Feed

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 threonine 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. Threonine was at 100% of NRC. Body weights on the crumble diets were significantly greater than on mash diets at each weighing. Raising the energy level of the crumble diets had little effect on the 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. The carcass yield data shows that breast meat yield was significantly greater on crumbles than from toms fed mash feeds.

In Ovo and Early Feeding Strategies

Short and long term increases in the proportion of breast meat can be achieved by feeding poults immediately post hatch (Noy and Sklan, 1999). In contrast, post-hatch starvation reduces the proportion of the *M. pectoralis superficialis* and overall breast meat yield when birds are compared to those given nutrients (Mozdziak *et al.*, 2002; Moore, 2005). The beneficial effects of *in ovo* delivery of various nutrients may include various production parameters including increased breast muscle size at hatch (Uni *et al.*, 2005; Foye *et al.*, 2006a).

Conclusion

The degree of emphasis on feeding to obtain breast meat yield will be dependent on feed cost and product specification. As greater breast meat deposition occurs by feeding with nutrient dense diets at increase in age. To increase the yield of high value breast meat in broiler chicks by developing early dietary and/or management intervention programs to stimulate initial muscle fibre numbers and subsequent breast muscle yield at an optimum market weight. Poultry breeders have to focus on selection for high percentages of breast meat resulting in chickens with a higher portion of breast. Maximize the capacity of 'supply' organs such as gut, respiratory, circulatory systems to supply the nutrients and metabolic homeostasis of the 'demand' tissues (meat, feathers and maintenance). Monitor the effect of early diet and/or management programs on development of growth-related metabolic disease, and on broiler flock uniformity and market

efficiency. Increasing apparent metabolizable energy (AME) particularly during cold or low temperatures improved the FCR but limited breast meat yield. Increasing crude protein, lysine and total sulphur containing amino acids concentrations by 4% in a diet formulated to contain 3,310 kcal/kg of AME ameliorated the negative response of breast meat yield associated with decreased AA intake of high AME diet (3,310 kcal of AME/kg) under moderate temperatures (24°C). The response to increasing dietary amino acid density early in development may relate to an increase in insulin-like growth factor-I concentrations which in turn, increases protein synthesis leading to larger muscle fiber diameter. Feeding broilers with high amino acid density diet from placement until 5 wk of age increases breast meat yield by 1.0% over broilers provided medium AA density diets, whereas 0.5% increase in breast meat yield occurred when high AA density diets were fed from 5 to 8 or 9 wk of age compared with feeding medium AA density diets. Dietary lysine x methionine and lysine x threonine interactions were apparent to optimize meat accretion. Increasing dietary lysine without an increase in methionine and threonine may limit protein synthesis. Betaine 0.1% plus 0.06% methionine increased breast meat yield in broilers than when they fed alone. Chelated trace mineral improves breast meat yield due to improved general bird health and greater bioavailability, resulting in fewer nutrients being directed to immune function and more being available for muscle deposition. Pellet and crumbles are having a positive effect on breast meat yield in broilers and turkeys.

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