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Growth Parameters and Carcass Quality of Broilers Fed a Corn-Soybean Diet Supplemented with Creatine Monohydrate

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Abstract: A six-week study was conducted to determine the feed efficiency and carcass quality of broilers supplemented creatine monohydrate. Day-old (unsexed) broiler chicks (n = 288) were allotted to one of three dietary treatments (12 chicks/pen, eight replications/treatment) using a completely randomized design. The control diet (diet A) contained 0% creatine throughout the entirety of the six week study. Diet B contained 0% creatine weeks 1-3 and 0.63% creatine weeks 4-6, while diet C contained 1.05% creatine weeks 1-3 and 0.63% creatine weeks 4-6. Each diet was formulated to meet or exceeded the nutrient requirements of broilers. During week four of the experiment, the feed efficiency of chicks fed diet B was superior ($P \leq 0.05$) to that of birds fed diet A. Intramuscular pH measured at 30 min postmortem was lower ($P \leq 0.05$) in the breast meat of broilers fed diet C. Moreover, the breast meat from broilers fed diets B and C was paler (higher L*-values) than that of birds fed the control diet ($P \leq 0.05$). In conclusion, the data indicate that feed efficiency was improved from weeks three to four after a creatine loading period. However, the carcasses from broilers fed creatine exhibited a paler breast meat color and a lower breast muscle pH (diet C) when compared to diet A.

Key words: Creatine, broilers, growth

Introduction

Creatine is an ergogenic aid that has recently garnered considerable interest within the scientific community. Human studies have successfully demonstrated that increased concentrations of intramuscular phosphocreatine (creatine chemically bound to a phosphate molecule) can result in an osmotic draw of fluid into the intracellular compartment of the muscle cell, ultimately increasing muscle cell volume (Ziegenfuss *et al*., 1998). This increase in muscle cell volume is thought to "superhydrate" the muscle cell, eventually triggering additional protein synthesis, minimizing protein breakdown, and increasing glycogen synthesis (Haussinger, 1996). In addition, human research trials have shown that creatine supplementation can significantly reduce the accumulation of lactic acid within muscle tissues following physical exercise (Prevost *et al*., 1997).

These findings are of interest to the poultry industry given that the major breast muscle of broilers and turkeys (*Pectoralis major*) contain primarily fast-twitch (type IIB) muscle fibers (von Lengerken *et al*., 2002) prone to rapid glycolytic metabolism. Fast twitch muscle fibers (IIB) have the capacity to generate large quantities of intramuscular lactic acid in postmortem muscle which could lead to increased protein degradation, a rapid reduction in muscle pH, and a decreased water-holding capacity, ultimately decreasing the retail value of fresh poultry. Consequently, the objective of this study was to determine if supplementation of creatine monohydrate for three to six weeks pre-harvest could significantly influence the feed efficiency, carcass yield, postmortem muscle pH, and breast meat color of broilers.

Materials and Methods

Live Animals: Day-old, straight run (unsexed) broiler chicks (n = 288) were purchased from a commercial hatchery, weighed, wing banded, and randomly assigned to floor pens within a University of Missouri-Columbia (UMC) negative-pressure, solid side-wall house. Birds were raised on litter and provided *ad libitum* access to both feed and water via plastic hanging feeders (Kuhl Corp., Flemington, NJ) and a bell-type drinker (Plasson Ltd., Israel). Initially, room temperature was maintained at approximately 29.4 ^{o}C and heat lamps were placed within each pen. Heat lamps were gradually raised and then turned off by the forth week of the study. Humidity was not monitored; however, a temperature controlled ventilation fan was used to remove excessive moisture from within the building. Broilers were provided with a continuous light source (24 h/d) throughout the entirety of the study.

A completely randomized design (CRD) was used to allocate birds into one of three dietary treatments (eight replicate pens of 12 chicks). Each diet consisted of a basic corn and soybean meal base (basal diet) formulated to meet or exceed the appropriate requirements (NRC, 1994) of growing broilers (Table 1). Test diets included diet A (control; basal diet containing 0% creatine weeks 1-6), diet B (basal diet containing 0% creatine from weeks 1-3; 0.63% creatine from weeks 4-6) and diet C (basal diet containing 1.05% creatine from

Table 1: Composition and selected nutrient content of experimental diets

Ingredient	Percentage of starter mix	Percentage of grower mix
Ground Corn	54.40	65.85
Soybean Meal (48%)	30.43	22.06
Corn Oil	5.22	3.18
Menhaden Fish Meal	3.50	3.50
Porcine Meat and Bone Meal	3.50	3.50
Sand or Creatine	1.05	0.63
Limestone	0.59	0.68
Dical Phosphate	0.52	0.04
Salt	0.35	0.22
DL-Methionine	0.16	0.05
[1]CA TMIN	0.11	0.11
Coban 60	0.08	0.08
[2]Vitamin Mix	0.05	0.05
[3]Selenium Mix	0.05	0.05
ME (Kcal.kg)	3200.00	3200.00
CP (%)	23.00	20.00

*Sand was used to replace creatine as filler when the inclusion was 0% of the diet. [1]Mineral mix provided in milligrams per kilogram of diet: MnO_2, 222; ZnO, 209; $FeSO_4$ _$7H_2O$, 654; $CuSO_4$, 32; ethylenediamine dihydroiodide, 1.9; $CaCO_3$, 160. [2]Supplied per kilogram of feed: vitamin A (retinyl acetate), 8,810 IU; cholecalciferol, 3,855 IU; vitamin E (dl-tocopheryl acetate), 14 IU; niacin, 55 mg; calcium pantothenate, 17 mg; riboflavin, 6.6 mg; pyridoxine, 2.2 mg; menadione sodium bisulfite, 1.7 mg; folic acid, 1.4 mg; thiamin mononitrate, 1.1 mg; biotin, 0.2 mg; cyanocobala-min, 11 µg; ethoxyquin, 83 mg. [3]Supplied 0.3 mg selenium per kilogram of feed.

weeks 1-3; 0.63% creatine from weeks 4-6). All test diets were isocaloric and isonitrogenous.

Chick and feed weights were recorded weekly to determine feed efficiency. In addition, pens were visually inspected on a daily basis for morbidity and mortality, each of which was documented as it occurred. It should be noted that after feed efficiency was recorded for week three, the third replicate from each of the three treatment groups was removed due to excessive mortality.

Carcasses: Birds were transported to the UMC abattoir to be humanely harvested after six weeks (42 d) on test. Approximately 30 min post-exsanguination, intramuscular pH was obtained in the center of the right side *Pectoralis major*. Intramuscular pH measurements were acquired using a glass tipped pH Star-Probe (SFK Technol., Peosta, IA) calibrated in pH 4.60 and 7.00 buffer solutions. Hot carcass weight (pre-rigor) was recorded immediately following evisceration and carcasses were placed in a chilled water bath for 20 h. After the 20 h chill, carcasses were fabricated and the fat pad, *Pectoralis major*, thigh, and drumstick were collected and weighed. Following fabrication, objective light reflectance values (CIE L*, a*, b*-values) were obtained from the outer surface of the right side *Pectoralis major*. Light reflectance was measured using a HunterLab MiniScan XE Plus Spectrophotometer (Hunter Associates Laboratory, Inc., Reston, VA) standardized to a black and white tile. Objective color measurements were recorded using a light source of D65 and a 10° standard observer. It is important to note that a Minolta surface spectrocolorimeter (Minolta Corp, Ramsey, NJ) has been used in many of the research projects involving the objective color measurements of poultry (Van Laack *et al.*, 2000; Fletcher *et al.*, 2000; Qiao *et al.*, 2002; Savenije *et al.*, 2002; Woelfel *et al.*, 2002). Consequently, the objective color measurements (CIE L*, a*, b*-values) described in the following text will differ from those values acquired in previous poultry projects.

Statistical Analysis: All data were analyzed by analysis of variance using the General Linear Models procedure (PROC GLM) of SAS (1990). Pen was used as the experimental unit within the analysis. Least square means showing significant differences were compared by Fisher's Protected LSD test. Statistical significance was accepted at $P \leq 0.05$.

Results and Discussion

Live Animals: Feed Performance. During week four of the experiment, the feed efficiency of chicks fed diet B was superior ($P \leq 0.05$) to that of birds fed diet A, suggesting that birds respond favorably to creatine loading when supplemented at 0.63% of the diet. Creatine supplementation has been shown to increase total body weight and shift fluid into the intracellular space, thereby significantly elevating total body and intracellular fluid (Ziegenfuss *et al.*, 1998). Moreover, creatine supplementation has been shown to increase total body (Casey and Greenhaff, 2000) and fat free mass (Mihic *et al.*, 2000) in humans in as little as one week. The results of this experiment, coupled with the information provided from previous research endeavors involving creatine ingestion (Casey and Greenhaff, 2000; Mihic *et al.*, 2000), suggest that the significant improvement in feed efficiency observed during week four of the experiment is most likely associated with an initial increase in muscle cellular hydration and the subsequent increase in weight gain.

Nevertheless, dietary treatment did not significantly affect the feed efficiency of broilers during weeks one, two, three, five, and six (Table 2). Moreover, the initial response to creatine supplementation was lost within a week's time and not at all evident in birds fed diet C. In addition, it is important to note that although significant differences in feed efficiency were observed during week four of the experimental test, no difference existed between the feed efficiency for diets A and B during week four and week three. Human trials (Ziegenfuss *et al.*,

Table 2: Least square mean values (+/- SEM) and the significance of creatine supplementation on broiler feed efficiency (total fed/total gained)

Variable	[1]Diet A	[2]Diet B	[3]Diet C	P-Value	Pooled SEM
Week 1	1.48	1.46	1.42	0.78	0.06
Week 2	1.78	1.82	1.62	0.13	0.08
Week 3	1.53	1.42	1.50	0.19	0.04
Week 4	1.53[a]	1.43[b]	1.46[ab]	0.03	0.03
Week 5	2.05	1.92	2.02	0.86	0.27
Week 6	2.12	2.16	2.27	0.27	0.07

[abc]Within a row, least square means not bearing a common superscript letter, are significant at ($P \leq 0.05$). [1]Diet A = 0% creatine throughout the entirety of the six week study. [2]Diet B = 0% creatine weeks 1-3 and 0.63% creatine weeks 4-6. [3]Diet C = 1.05% creatine weeks 1-3 and 0.63% creatine weeks 4-6.

Table 3: Least square mean values (+/- SEM) and the significance of creatine supplementation on broiler carcass quality

Variable	[1]Diet A	[2]Diet B	[3]Diet C	P-Value	Pooled SEM
Hot Carcass Wt. (g)	1763.98	1737.73	1694.41	0.12	24.26
Fat Pad Wt. (g)	49.44	49.86	49.26	0.95	1.52
Intramuscular pH	5.78[a]	5.75[ab]	5.68[b]	0.05	0.03
P. major Wt. (g)	176.07	169.45	167.26	0.35	4.37
Drumstick Wt. (g)	247.48	245.75	238.20	0.15	3.37
Carcass Shrink (g)	105.19	104.93	105.98	0.77	1.08
CIE L*-value	53.96[a]	55.84[b]	56.33[b]	0.0001	0.20
CIE a*-value	9.05	9.36	9.13	0.69	0.26
CIE b*-value	23.95	23.85	24.48	0.30	0.30

[abc]Within a row, least square means not bearing a common superscript letter, are significant at ($P \leq 0.05$). [1]Diet A = 0% creatine throughout the entirety of the six week study. [2]Diet B = 0% creatine weeks 1-3 and 0.63% creatine weeks 4-6. [3]Diet C = 1.05% creatine weeks 1-3 and 0.63% creatine weeks 4-6.

1998) have demonstrated that hydration of the intracellular compartment, and subsequent gain in bodyweight, occurs within the first three days of supplementation. These findings support the hypothesis that the initial, yet short lived increase in feed conversion was the result of muscle cellular hydration, an effect that waned as the intracellular compartments of the muscle cell became saturated.

Carcass weights and yields: Dietary treatment did not affect hot carcass and fat pad weights, nor did it affect thigh, drumstick, and breast meat yield (Table 3). These results parallel previous studies involving the supplementation of creatine to swine (Maddock *et al.*, 2000; O'Quinn *et al.*, 2000), each of which found that dietary treatment had little to no effect on dressing percentage and fat deposition. Additionally, no differences in carcass shrink were noted among the three dietary treatments in the present study. Therefore, it is possible that: 1) supplemental levels of CMH were not high enough to realize the ergogenic benefits previously seen in human research; or 2) genetic selection has enabled today's growing broiler to meet its genetic propensity for lean gain accretion, regardless of creatine supplementation.

Intramuscular pH: Dietary treatment affected the intramuscular pH of poultry breast meat, with significant differences noted among two of the three treatment groups (Table 3). When measured at 30 min postmortem, the breast meat of birds fed diet C had a lower ($P \leq 0.05$) intramuscular pH than the breast meat of birds fed diet A. Nevertheless, the intramuscular pH values exhibited among all three treatment groups did not fall within the pH range typically associated with an unacceptable lean color. Research (Van Laack *et al.*, 2000) has shown that contrary to the pale, soft and exudative (PSE) condition found in pork meat, the pale color of chicken can occur at a pH of 5.7, much further from the isoelectric point of the muscle proteins action and myosin than that of PSE pork (pH of 5.4). Furthermore, the aforementioned study (Van Laack *et al.*, 2000) found that pale broiler breast meat exhibits very little drip loss. These findings clarify previous research involving the interrelationship between intramuscular pH and broiler breast meat color (Qiao *et al.*, 2002) which has demonstrated that although a negative correlation exists between meat lightness and ultimate pH, raw muscle pH does not correlate with final product moisture and shear force values of poultry breast meat.

Nevertheless, a lower breast muscle pH, coupled with a higher L*-value (Table 3), may in fact be beneficial from

a retail perspective. Psychrotrophic bacteria, a major contributor to the spoilage of fresh poultry, grows well at refrigeration temperatures (3 °C) and are known to multiply on the surface of poultry meat using glucose and other carbohydrates as energy sources (Allen *et al.*, 1997). Research conducted by Livingston and Brown (1981) and Newton and Gill (1981) found that the shelf life of fresh poultry is greater in meat that possesses a lower intramuscular pH, and subsequent paler appearance, by lengthening the lag phase time of these psychotropic bacteria. This phenomenon most likely occurs because there is less readily available glucose within the muscle tissues of poultry possessing a lower intramuscular pH.

Objective color: Poultry meat color is affected by a number of factors such as bird age, sex, strain, diet, intramuscular fat, meat moisture content, pre-slaughter conditions and processing variables (Northcutt, 1997). Each of these factors inevitably contributes to the consumer's selection of fresh meat at the retail level and to the final evaluation and acceptance of a meat product at the time of consumption (Fletcher *et al.*, 1999). Excluding diet and sex, each of the aforementioned pre- and post-slaughter variables know to affect poultry meat color were held constant throughout the study. Compared with the breast meat of broilers fed diet A, the breast meat of broilers fed diets B and C possessed higher ($P \leq 0.05$) L*-values (Table 3). Nevertheless, no differences in a* and b*-values were noted among the three dietary treatments. Given that the human eye is less adept at detecting differences in color and hue than is a spectrophotometer, it is difficult to determine whether an untrained consumer panel could have perceived these treatment differences when selecting product in a retail setting.

Conclusion: The feed performance of broilers was significantly improved following creatine loading (diet B), a response that waned during weeks five and six of the experiment. Carcass yield, as measured by hot carcass weight, fat pad weight, and breast and drumstick weight, was not affected by creatine supplementation for three and six weeks pre-harvest. Additionally, creatine supplementation did not buffer the intramuscular pH decline of the *Pectoralis major* when measured 30 min postmortem and resulted in a paler breast meat color (higher CIE L*-values). Nevertheless, the differences noted in the CIE L*-values and intramuscular pH do not fall within the range of values typically associated with PSE breast meat. In fact, the lower pH and higher CIE L*-values found in breast meat of birds fed CMH may help to decrease the prolificacy of psychrotrophic bacteria, thus extending the shelf-life of fresh poultry. These findings suggest that further analysis must be run to determine if 1) the consumer can ascertain the differences observed in objective color when choosing fresh poultry meat in the retail setting, 2) the lower intramuscular pH associated with dietary treatment significantly affects poultry meat tenderness, and 3) dietary supplementation of creatine does indeed decrease the psychrotrophic plate count of fresh poultry meat, thus extending its shelf-life.

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References

Allen, C.D., S.M. Russell and D.L. Fletcher, 1997. The relationship of broiler breast meat color and pH to shelf-life and odor development. Poult. Sci., 76: 1042-1046.

Casey, A.D. and P.L. Greenhaff, 2000. Does dietary supplementation play a role in skeletal muscle metabolism and performance?[1-4] Am. J. Clin. Nutr., 72(suppl): 607S-17S.

Fletcher, D.L., 1999. Broiler breast meat color variation, pH, and texture. Poult. Sci., 78: 1323-1327.

Fletcher, D.L., M. Qiao and D.P. Smith, 2000. The relationship of raw broiler breast color and pH to cooked meat color and pH. Poult. Sci., 79: 784-788.

Haussinger, D., 1996. The role of cellular hydration in the regulation of cell cunction. Biochem. J., 313: 697-710.

Livingston, D.J. and W.D. Brown, 1981. The chemistry of myoglobin and its reactions. Food Tec., 35: 244-252.

Maddock, R.J., B.S. Bidner, S.N. Carr, F.K. McKeith, E.P. Berg and J.W. Savell, 2000. Supplementation with creatine monohydrate improved the lean quality of fresh pork of two different genotypes. Proc. Rec. Meat Confr., 53: 118.

Mihic, S., J.R. MacDonald, S. McKenzie and M.A. Tarnopolsky, 2000. Acute creatine loading increases fat-free mass, but does not affect blood pressure, plasma creatine, or CK activity in men and women. Med. Sci. Sports Exerc., 32: 291-296.

Newton, K.G. and C.O. Gill, 1981. The microbiology of DFD fresh meats: A Review. Meat Sci., 5: 223-232.

Northcutt, J.K., 1997. Factors affecting poultry meat quality. Tech. Bull. No. 1157. Univ. of Georgia, Athens.

NRC, 1994. Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC.

O'Quinn, P.R., B.S. Andrews, R.D. Goodband, J.A. Unruh, J.L. Nelssen, J.C. Woodworth, M.D. Tokach and K.Q. Owen, 2000. Effects of modified tall oil and creatine monohydrate on growth performance, carcass characteristics, and meat quality of growing-finishing pigs. J. Anim. Sci., 78: 2376-2382.

Prevost, M.C., A.G. Nelson and G.S. Morris, 1997. Creatine supplementation enhances intermittent work performance. Res. Quarterly Exercise Sport., 68: 233-240.

Qiao, M., D.L. Fletcher, D.P. Smith and J.K. Northcutt, 2002. Effects of raw broiler breast meat color variation on marination and cooked meat quality. Poult. Sci., 81: 276-280.

SAS, 1990. SAS Users Guide: Statistics. SAS, Inc., Cary, NC.

Savenije, B., E. Lambooij, M.A. Gerritzen, K. Venema and J. Korf, 2002. Effects of feed deprivation and transport on preslaughter blood metabolites, early postmortem metabolites and meat quality. Poult. Sci., 81: 699-708.

Van Laack, R.L.J.M., C.-H. Liu, M.O. Smith and H.D. Loveday, 2000. Characteristics of pale, soft, exudative broiler breast meat. Poult. Sci., 79: 1057-1061.

von Lengerken, G., S. Maak and M. Wicke, 2002. Muscle metabolism and meat quality of pigs and poultry. Veterinarija Ir Zootechnika. T. 20 (42).

Woelfel, R.L., C.M Owens, E.M. Hirschler, R. Martinez-Dawson and A.R. Sams, 2002. The characterization and incidence of pale, soft, and exudative broiler meat in a commercial processing plant. Poult. Sci., 81: 579-584.

Ziegenfuss, T.N., L.M. Lowery and P.W.R. Lemon, 1998. Acute Fluid Volume Changes in Men During Three Days of Creatine Supplementation. On-line J. Exerc. Physiol. [serial online]. October; Vol. 3.