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Research article

Evaluation of dietary spray-dried bovine plasma fed to turkeys during brooding on performance to market age

Ashley A. Gernat[1], **Joy Campbell**[2], **Adam Fahrenholz**[1] **and Jesse Grimes**[1*]

[1] Prestage Department of Poultry Science, North Carolina State University, Raleigh NC 27695, USA
[2] APC Proteins LLC, IA 50021, USA

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***Corresponding author:**
Jesse Grimes
jgrimes@ncsu.edu

Abstract

Commercial turkey production can experience an economic loss due to exposure of birds to stress. Turkeys can undergo various levels of stress, including, but not limited to, hatching, brooding/growing, and transport. Temperature, climate, heat, and cold stress are major livestock stressors associated with economic losses. Exposure to stress also causes an increased probability of infections and diseases that have a negative financial impact on production. In this study, Large White commercial turkey hens were reared for 12 weeks (wk) to evaluate their stress responses and performance alterations due to induced stress through a mimic of brooder house to grow-out transition. Parameters for performance, blood, and meat yield were recorded. Spray-dried bovine plasma (SDBP) was formulated iso-nutritionally into the diets. SDBP has been shown to be an ingredient in animal diets that may help support immune health and positively affect performance. This ingredient was used for a total of 6 wk in the starter and grower-1 diets at different inclusion percentages. Treatments included a control diet (0% SDBP), 1.0% (SDBP1), and 2.0% (SDBP2) inclusion. At 6 wk, common diets were fed (grower-2 and finisher-1). At 5 wk management-based stressors were applied for 24 hours (h): feed and water restriction and reduced house temperature. Previously used pine shavings were used for bedding. No significant variances were noted in body weight, weight gain, or feed consumption as a result of the different feed treatments. However, during the sixth week, the feed conversion ratio (FCR) was improved due to SDBP inclusion. The FCR for SDBP1 (1.90) and SDBP2 (1.97) birds was lower than that of the control diet-fed birds (2.04). No difference in FCR was observed at 12 wk. A significant difference was observed for corticosterone levels post-stress: SDBP1 (23.81 ng/mL) and SDBP2 (19.17 ng/mL) were higher than that of the control birds (16.40 ng/mL). Further research is needed to ascertain the impact of SDBP on the immune function and production of turkeys.

Keywords: Turkeys, Performance, Stress, Corticosterone, Nutrition, Spray-dried plasma

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Introduction

Consumers are increasingly concerned about antibiotic usage in food animal production. Thus, the market for birds reared with no antibiotic growth promotors (AGP), antibiotic-free programs (ABF), or no antibiotics ever (NAE) (Gould, 2012) is rising, thus, creating opportunities for producers to develop substitutions for antibiotics or solutions for consumer concerns. Although antibiotics have never been ideal, the industry faces health issues that need to be addressed when it comes to producing safe food products. Diseases caused by poor management, non-optimum environmental conditions, transportation, and more appear to cause not only stress but also economic losses for the poultry industry (Lutful Kabir, 2009). Having a low-stress environment is considered desirable for general livestock production.

Stress responses are perceived in various ways and are described differently within individual growing conditions. The physiological response(s) to a stressor is defined as a state of the actual or perceived threat to homeostasis (Smith and Vale, 2006; Koutsos and Klasing, 2014). Optimum production in animals is reduced by many stressors, such as the environment (heat and cold, increased population density, ammonia, wet litter), infection (bacterial, viral, and parasitic), nutrition (unbalanced feeds, no feed, oxidized feed ingredients), and many other factors e.g., increased noise levels, strange animal invasions, etc. The resultant physiological alterations called stress indicate the continuous need for improvements in the science of animal management and housing technology to meet the needs of genetically improved flocks. The environment may be the most crucial factor affecting turkey's productivity.

In the case of the turkey's environment, one must be conversant in factors such as methods of confinement, management system, bird surroundings, and their relationship, and of course, thermodynamics within the barns housing of the turkeys. Maintaining proper conditions such as correct temperature, air movement, humidity, light levels, and access to feed and water can reduce stress-related responses, directly affecting performance and production. Factors such as cold, heat, stocking density, diseases, or other stressors can affect feed intake and growth, negatively impacting the birds' immune system (Abo-Al-Ela et al., 2021). During severe stress reactions, the immune system becomes compromised by the adaptive physiological changes occurring in the birds' bodies.

Immunosuppression can occur because of either acute (short-term) or chronic (long-term) stress. The difference between acute and chronic stress is the duration of that stress and the specific and non-specific stress responses observed in each condition. Acute stress can have long-term effects on poultry production and economics. Exposure time to stressors can also harm the immune system due to interactions with the stress hormone corticosterone (Dixon et al., 2016). Corticosterone, the avian stress hormone, acts on cardiovascular, immune, behavioral, and metabolic regulations in birds (Smith and Vale, 2006). Responses to stressors can be specific or non-specific, involving the endocrine, immune, and nervous systems (Smith and Vale, 2006).

The use of animal by-products in animal and poultry feed may be restricted or reduced in some areas or markets and can be affected by policies or consumer preferences (Ominski et al., 2021; Amato et al., 2023). However, there are many opportunities and advantages for the use of animal by-product proteins in livestock and poultry feed (Sandström et al., 2022). One product that receives considerable attention in the livestock and poultry industry is spray-dried plasma (SDP) usually either bovine or swine derived. The SDP is a highly digestible protein ingredient rich in functional molecules and manufactured from animal blood collected from federally inspected slaughter facilities (Coffey and Cromwell, 2001; APC, 2019). This is later spray-dried to preserve the proper functioning of its components. Some of the proteins, peptides, and nutrients contained in SDP include albumen, globulins, immunoglobulins, transferrin, amino acids, cytokines, growth factors, and other nutritional components that are reportedly beneficial to animals (APC, 2019; Belote et al., 2021). Dietary constituents usually neither directly stimulate the immune system nor interfere with its functions. However, many nutritional ingredients appear to modulate or enhance faster and more efficient responses (APC, 2019; Abo-Al-Ela et al., 2021). Although SDP has been tested primarily in pigs, mice, and rats, chickens respond positively to SDP (Campbell et al., 2006; Song et al., 2015; Zhang et al., 2016; Campbell et al., 2019). In addition, the effects of SDP are not limited to the gastrointestinal system but also enhance the respiratory and reproductive systems (Liu et al., 2014; Song et al., 2015). Immunomodulation can be defined as any manipulation of the immune system using exogenous means to control infections and other adverse health effects (Petrovsky and Aguilar, 2004). Nutritional immunomodulation can be defined as the supplementation of a specific dietary nutrient or feed additive that can cause an alteration in the immune system's function to achieve a certain goal (Korver, 2012). Turkeys and chickens, although very dissimilar in many aspects of their development and physiological capabilities, do share some physical characteristics. One of the greatest physical differences resides in their growth to a market age-related which is associated with their body size. Turkey's production has an inherently higher economic risk associated with many aspects of its production conditions. As they age and grow heavier, the potential costs of daily losses increase significantly. Thus, turkey flock management is very demanding, requiring close observation to intervene in developing growth problems, including the immune system's functioning.

Turkeys grow through critical stress periods, one being associated with early poult mortality during 1-10 and 10-20 days post-hatch. A second period is associated with the transfer from brooding facilities to grow-out or rearing houses at 4 to 6 wk of age. A third is associated with load out for transportation to the processing plant. When being transferred to grow-out houses, turkeys are restricted from feed and water for some short period (hours) and can be exposed to heat or cold temperatures, depending on the year's season. During brooding and rearing, turkeys can also be exposed to potential pathogens. Exposure to pathogens during stress can increase the risk of production and efficiency losses.

Thus, considering these three vital periods during the development of marketable birds, the birds must possess a solid immune system. Broiler chickens fed SDP have shown meaningful post-hatch developmental responses; however, little is known about SDP effects on turkeys. Thus, in this study, the objective was to test different levels of dietary bovine spray-dried plasma (SDBP) fed to turkeys during the brooder period and document their performance and development as influenced by a short-term management-induced stressor while the birds were reared under less-than-optimal conditions.

Materials and methods

Animal ethics

All bird handling procedures were approved by the NC State University Institutional Animal Care and Use Committee (Protocol 18-155-A). All participants in this project were properly trained to handle animals. Turkeys were observed at least twice a day, in

Table 1: Starter diet ingredients and nutrient composition of dietary treatments fed to turkey hens for 0-3 wk.

Ingredient, % "as-fed"	**Control**	**SDBP1**	**SDBP2**
Age fed (wk)	0 to 3	0 to 3	0 to 3
Form	Crumble	Crumble	Crumble
Corn	23.60	25.0	26.10
Soybean meal, 46 % crude protein	33.40	31.60	30.00
Poultry by-product meal	10.00	10.00	10.00
Wheat	20.0	20.0	20.0
Poultry fat	6.765	6.265	5.865
Monocalcium phosphate, 21% P	2.500	2.475	2.450
Limestone	1.800	1.825	1.850
L-Lysine-HCl (78%)	0.460	0.440	0.410
D-L Methionine	0.425	0.425	0.430
Sodium bicarbonate	0.15	0.15	0.15
Choline chloride (60%)	0.20	0.20	0.20
Vitamin premix[1]	0.20	0.20	0.20
Trace mineral premix[2]	0.20	0.20	0.20
Salt	0.20	0.14	0.08
L-Threonine	0.05	0.03	0.015
Selenium mix, 0.06%[3]	0.05	0.05	0.05
SDBP[4]	0	1.000	2.000
Total %	100.00	100.00	100.00
Calculated analysis, % (unless otherwise noted)			
AMEn, kcal/lb	1,377	1,377	1,377
Crude protein	28.1	28.1	28.1
Crude protein (analyzed)	28.0	28.1	28.2
Digestible lysine	1.61	1.61	1.61
Calcium	1.51	1.51	1.51
Sodium	0.18	0.18	0.18
Fat	9.94	9.47	9.10

Abbreviation: AME_n, apparent metabolizable energy.

[1]Vitamin premix includes per kg of diet: Vitamin A (Vitamin A acetate), 6600 IU; Vitamin D (cholecalciferol), 1980 IU; Vitamin E (DL-alpha tocopherol acetate), 33 IU; menadione (menadione sodium bisulfate complex), 2 mg; Vitamin B12 (cyanocobalamin), 0.02 mg; folacin (folic acid), 1.1 mg: D-pantothenic acid (calcium pantothenate), 11 mg; riboflavin (riboflavin), 6.6 mg; niacin (niacinamide), 55 mg; thiamin (thiamin mononitrate), 2 mg; D-biotin (biotin), 0.13 mg; and pyridoxine (pyridoxine hydrochloride), 4 mg.

[2]Mineral premix include per kg of diet: Mn (manganese sulfate), 120 mg; Zn (zinc sulfate), 120 mg; Fe (iron sulfate monohydrate), 80 mg; Cu (tri-basic copper chloride), 10 mg; I (ethylenediamine dihydriodide), 2.5 mg; and Co (cobalt), 1 mg.

[3]Selenium mix provided Se at 0.3 mg/kg of feed.

[4]SDBP, spray-dried bovine plasma feed ingredient (AP 920, APC LLC., Ankeny, IA USA).

the morning and afternoon. All mortalities were removed, and body weight was recorded. The weight of unused feed was recorded. Birds removed from this study due to any health issue were properly and humanely euthanized.

Turkey management

A total of 1440 Large White commercial turkey hen poults (Aviagen-Turkeys, 2023b) "Nicholas Select, Aviagen Turkeys, Lewisburg, WV" were obtained from a commercial hatchery (Prestage Family Farms, Clinton, NC) and transported to the NC State University Talley Turkey Education Unit (Raleigh, NC). All birds were beak and toe conditioned. The birds were then placed in a curtain-sided house with concrete floors. The house was equipped with fans for negative air pressure power ventilation. The house consisted of 48 pens (2.44×3.51 m) organized in 4 blocks of 12 pens each. Each pen housed 30 birds which were reduced to 28 birds per pen at six weeks of age due to sampling. One bell poultry bell-type Plasson drinker and one tube feeder were placed in each pen. During the first week of brooding, the poults were reared in brooder rings inside each pen. Also, during the first week (wk), additional supplemental drinkers and feeders were provided. The rings, as well as the supplemental feeders and drinkers, were removed after seven days of age. Heat lamps fitted with thermostats for temperature control were placed in each ring and were used according to bird comfort.

House temperature was controlled with gas-fired heaters located in the house hallways. House temperature was set at 32°C for two days, 31°C for two days, and 29°C for ten days. Beginning at wk 3, house temperature was decreased by 2°C each wk until the ambient temperature was reached. The lighting program photo phase was set at 14 hours per day us-

Table 2: Grower-1 diet ingredients and nutrient composition of dietary treatments fed to turkey hens from 3-6 wk.

Ingredient, % "as-fed"	**Control**	**SDBP1**	**SDBP2**
Age fed (wk)	0 to 3	0 to 3	0 to 3
Form	Crumble	Crumble	Crumble
Corn	32.10	33.40	34.55
Soybean meal, 46 % crude protein	26.30	24.60	23.00
Poultry by-product meal	10.00	10.00	10.00
Wheat	20.0	20.0	20.0
Poultry fat	5.845	5.373	4.935
Monocalcium phosphate, 21% P	2.300	2.250	2.225
Limestone	1.600	1.625	1.650
L-Lysine-HCl (78%)	0.445	0.415	0.380
D-L Methionine	0.355	0.357	0.360
Sodium bicarbonate	0.15	0.15	0.15
Choline chloride (60%)	0.20	0.20	0.20
Vitamin premix[1]	0.20	0.20	0.20
Trace mineral premix[2]	0.20	0.20	0.20
Salt	0.20	0.14	0.08
L-Threonine	0.055	0.040	0.020
Selenium mix, 0.06%[3]	0.05	0.05	0.05
SDBP[4]	0	1.000	2.000
Total %	100.00	100.00	100.00
Calculated analysis, % (unless otherwise noted)			
AMEn, kcal/lb	1,406	1,406	1,406
Crude protein	25.1	25.1	25.1
Crude protein (analyzed)	26.4	25.1	25.6
Digestible lysine	1.43	1.43	1.43
Calcium	1.38	1.38	1.38
Sodium	0.18	0.18	0.18
Fat	9.23	8.78	8.37

Abbreviation: AME_n, apparent metabolizable energy.
[1]Vitamin premix includes per kg of diet: Vitamin A (Vitamin A acetate), 6600 IU; Vitamin D (cholecalciferol), 1980 IU; Vitamin E (DL-alpha tocopherol acetate), 33 IU; menadione (menadione sodium bisulfate complex), 2 mg; Vitamin B12 (cyanocobalamin), 0.02 mg; folacin (folic acid), 1.1 mg: D-pantothenic acid (calcium pantothenate), 11 mg; riboflavin (riboflavin), 6.6 mg; niacin (niacinamide), 55 mg; thiamin (thiamin mononitrate), 2 mg; D-biotin (biotin), 0.13 mg; and pyridoxine (pyridoxine hydrochloride), 4 mg.
[2]Mineral premix include per kg of diet: Mn (manganese sulfate), 120 mg; Zn (zinc sulfate), 120 mg; Fe (iron sulfate monohydrate), 80 mg; Cu (tri-basic copper chloride), 10 mg; I (ethylenediamine dihydriodide), 2.5 mg; and Co (cobalt), 1 mg.
[3]Selenium mix provided Se at 0.3 mg/kg of feed.
[4]SDBP, spray-dried bovine plasma feed ingredient (AP 920, APC LLC., Ankeny, IA USA).

ing LED lights. Turkeys were weighed individually at placement, 3, 5, 6, 9, and 12 wk of age. Weights were recorded to calculate feed intake, weight gain, and feed conversion ratio (FCR). The body weights (BW) or gains for all birds removed from the study were used in calculating the FCR.

The usual management of young turkey poults is to provide a dry brooding environment with unused clean bedding. In this study, rearing conditions were slightly compromised. The center hallway of the house was sprayed with water daily for six weeks to increase house humidity. Instead of only unused, clean bedding, fresh pine wood shavings were topped with old litter from a previous flock and used as the birds' bedding. In addition, moving birds from one location to another for transition from a brooder house to a grow-out house can result in the birds experiencing some stress levels. In this study, two actions were used to simulate a winter move from a brooder house to a grow-out house, similar to those described by Bartz et al. (2018). First, birds do not receive feed or water during this physical transport. In addition, it is not atypical for grow-out houses in some areas of turkey production to not have heaters. Therefore, at 5 wk, the feed and water were removed for 24 h. In addition, the house temperature was decreased to 12°C for 24 h.

Feed

All feeds were manufactured at the North Carolina State University Feed Mill Education Unit. In this study, three different types of feed were tested. Each feed treatment has 16 pens of birds, and they were equally distributed across the four blocks of pens. In each block, there were four pens of birds for

Table 3: Common grower 2 and finisher 1 diet ingredients and nutrient composition of feed fed to turkey hens from 6-12 wk.

Ingredient, % "as-fed"	Grower 1	Finisher 1
Age fed (wk)	6 to 9	9 to 12
Form	Pellets	Pellets
Corn	38.80	43.30
Soybean meal, 46 % crude protein	20.0	15.50
Poultry by-product meal	10.00	10.00
Wheat	20.0	20.0
Poultry fat	5.920	6.590
Monocalcium phosphate, 21% P	1.950	1.800
Limestone	1.450	1.250
L-Lysine-HCl (78%)	0.460	0.275
D-L Methionine	0.350	0.210
Sodium bicarbonate	0.15	0.15
Choline chloride (60%)	0.20	0.20
Vitamin premix[1]	0.20	0.20
Trace mineral premix[2]	0.20	0.20
Salt	0.20	0.20
L-Threonine	0.070	0.075
Selenium mix, 0.06%[3]	0.05	0.05
Total %	100.00	100.00
Calculated analysis, % (unless otherwise noted)		
AMEn, kcal/lb	1,450	1,500
Crude protein	22.4	20.2
Crude protein (analyzed)	23.4	21.5
Digestible lysine	1.29	1.04
Calcium	1.25	1.14
Sodium	0.18	0.18
Fat	9.43	10.17

Abbreviation: AME_n, apparent metabolizable energy.
[1]Vitamin premix includes per kg of diet: Vitamin A (Vitamin A acetate), 6600 IU; Vitamin D (cholecalciferol), 1980 IU; Vitamin E (DL-alpha tocopherol acetate), 33 IU; menadione (menadione sodium bisulfate complex), 2 mg; Vitamin B12 (cyanocobalamin), 0.02 mg; folacin (folic acid), 1.1 mg: D-pantothenic acid (calcium pantothenate), 11 mg; riboflavin (riboflavin), 6.6 mg; niacin (niacinamide), 55 mg; thiamin (thiamin mononitrate), 2 mg; D-biotin (biotin), 0.13 mg; and pyridoxine (pyridoxine hydrochloride), 4 mg.
[2]Mineral premix include per kg of diet: Mn (manganese sulfate), 120 mg; Zn (zinc sulfate), 120 mg; Fe (iron sulfate monohydrate), 80 mg; Cu (tri-basic copper chloride), 10 mg; I (ethylenediamine dihydriodide), 2.5 mg; and Co (cobalt), 1 mg.
[3]Selenium mix provided Se at 0.3 mg/kg of feed.

Table 4: Mean Body Weight (kg/bird) of large white turkey hens reared to 12 weeks of age.

Diet	0 d	3 wk	5 wk pre-stress	5 wk 1d ost-stress	6 wk	9 wk	12 wk
Control	0.052	0.496	1.215	1.137	1.700	3.949	6.757
SDBP1[1]	0.052	0.519	1.225	1.138	1.710	3.964	6.555
SDBP2[2]	0.052	0.499	1.217	1.141	1.738	3.962	6.577
SEM	0.000	0.009	0.020	0.017	0.021	0.041	0.055
P-value	0.453	0.204	0.922	0.983	0.441	0.958	0.952

[1]SDBP at 1% of the diet
[2]SDBP at 2% of the diet

each feed treatment. There were four feed phases throughout rearing the birds: starter 1 (S1), grower-1 (G1), grower-2 (G2), and finisher-1 (F1). The nutrient composition of each phase ration was based on the breeder's recommendation (Aviagen-Turkeys, 2023a). Each feed phase was fed to the birds for three weeks. Bovine spray-dried plasma (SDBP) (AP920, APC, LLC, Ankeny, IA USA) was formulated iso-nutritionally into the diets to create the three feed treatments. The product contains 78% crude protein (APC, AP920) and was used for a total of six wk in the early feed phases (starter 1 and grower 1) at different inclusion percentages.

Treatments included a control diet (0% SDBP), 1.0% (SDBP1) and 2.0% SDBP inclusion (SDBP2). After six weeks, common diets were fed to all birds (grower-2 and finisher-1). The S1 and G1 were crumbled from pellets, while the G2 and F1 diets were fed as pellets (Table 1, Table 2, Table 3). Feed and water were made available to all birds on an *ad libitum* basis. Feed phases were provided by age (3 wk each), meaning that the remaining feed was removed after weighing back (feeder and feed were weighed) each day of feed phase change. Feed phases were 0-3, 3-6, 6-9, and 9-12 wk. Weights of feed added were recorded on pen sheets.

Carcass yield

At 12 wk, two birds per pen were selected based on average body weight per pen. Birds were humanely stunned using a stunning knife (Model VS200, Midwest Processing Systems, Eden Prairie, MN, USA) and slaughtered for processing. On the first day of processing, the empty carcass weights were recorded. After chilling overnight in ice water, the empty carcasses were weighed and cut up for carcass yield determination. The hen hot carcass weight was measured to calculate carcass yield (in relation to the body weight at slaughter), and parts yields were based on empty chilled carcass weights.

Blood analysis

Blood was collected from two different birds per pen via the brachial wing vein on the day before stress at 5 wk, the day after stress, and three weeks post-stress (8 wk). Blood plasma was analyzed to determine corticosterone (CORT). A volume of 3 mL of blood was collected in heparinized needles and syringes from different birds each sampling day by trained individuals. Samples were then placed in individual borosilicate glass culture tubes containing heparin. Samples were later centrifuged at 500 ×g for one hour to ensure proper plasma separation. Plasma was collected into individual plastic vials that were frozen and then stored at -80°C in the freezer until corticosterone analysis could be completed. A corticosterone EIA assay kit (Cayman Chemical, Ann Arbor, MI, USA) was used for CORT determination.

Bone measurements

Bone growth and health were measured based on the methods reported by Malheiros et al. (2022). The right tibia from each bird was collected at 12 wk to measure bone dimensions and ash content. Cartilaginous caps were manually removed. Bones were weighed and measured using the 3-point bend method, where different measurements were taken utilizing a digital 12” caliper (iGAGING) connected to the computer by a data logger. The bones’ diameter and length were determined through this process. Bone breaking strength was measured by applying a force perpendicular to the bone’s diaphysis, where bones were placed on 2 support points measuring 3 cm apart. Using a 250 kg load cell and a crosshead speed of 100mm/min, the force of a shear plate measuring 8 cm x 1 mm was applied to the midpoint of each bone. Bones were broken in half once the force was applied. Samples were dried at 105°C for 12 h and then defatted for 72 h using Soxhlet petroleum ether in a glass container. The bones were dried again in a drying oven for 24 h. Then they were weighed and ashed in a muffle furnace at 600°C for 18 h. Bone ash (bone mineral content) was expressed as a percent of the dry defatted bone weight and as the weight of the tibia in grams.

Statistical analysis

The data in this study were analyzed using a complete randomized block design using ANOVA in JMP® 15, SAS Institute Inc., Cary, NC. Means were separated using Tukey’s HSD procedure within JMP and significance was recognized at $P \leq 0.05$ for all performance and blood data. The pen was the experimental unit for the performance data and the bird was the experimental unit for the blood and processing data. The normality of the data was tested using the Distribution Function of JMP. Over the 12-week period, the weight data displayed a normal distribution and the average and median weights remained the same across all pens.

Results and discussion

The model used in this study provided less than optimal brooding conditions, and simulating possible conditions experienced by turkeys during transportation from brooder to rearing facilities successfully elicited both a performance response and a plasma corticosterone response. This was observed with bird behavior and growth and their changes in plasma corticosterone levels which increased from pre- to post-stress. While birds gained weight throughout the study, the hens underperformed compared to commercial breeder standards. In contrast to Aviagen standards for Nicholas Select commercial hens (Aviagen-Turkeys, 2023b), the BW at 12 wk of age is suggested as 8.23 kg. In contrast, the control birds in this trial had a mean BW of 6.757 kg/bd (Table 4). This represents a 17.8% reduction in expected 12 wk BW based on the Aviagen standard. The reduced gain for birds in this trial could be due to the less optimal rearing conditions purposefully imposed during the trial. The Aviagen target feed intake at 12 wk is 15.8 kg, whereas, for the study herein, control birds consumed 14.3 kg/bd (Figure 1). The FCR was also impaired due to the less-than-optimal growth where the Aviagen standard is 1.86, and the control birds had an FCR of 2.18 (Figure 2).

No significant differences were observed for BW (Table 4) or BW gain (Table 5) due to diet throughout the trial. Various researchers have noted the positive effects of feeding SDP, from either bovine or swine sources, on BW gain. The SDBP appears to be more effective under stress conditions than under non-challenged situations (van Dijk et al., 2001). Campbell et al. (2006) noted an advantage in average daily gain in SDBP-fed broilers with necrotic enteritis.

There was no effect of diet on feed intake (Figure 1). Henn et al. (2013) noted improved feed intake

Table 5: Mean body weight gain (kg/bird) of turkey poults fed dietary supplements of spray-dried bovine plasma.

Diet	3-6 wk	6-9 wk	9-12 wk
Control	1.204	2.248	2.626
SDBP1[1]	1.191	2.254	2.590
SDBP2[2]	1.238	2.224	2.614
SEM	0.0193	0.333	0.023
P-value	0.2149	0.7989	0.5608

[1]SDBP at 1% of the diet
[2]SDBP at 2% of the diet

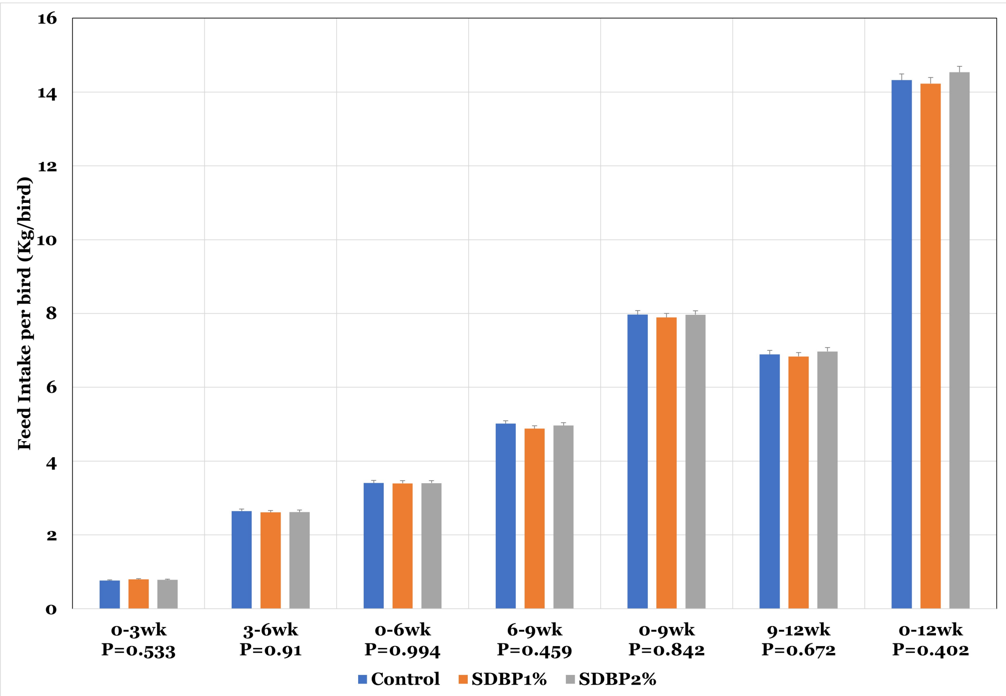

Figure 1: Feed Intake (kg/bird) of hen turkey poults fed diets supplemented with spray-dried bovine plasma (SDBP).

in SDBP-fed broilers subjected to challenging health conditions. Campbell et al. (2006) also observed increased feed intake in broilers facing a necrotic enteritis challenge on continuous or discontinued feed containing SDBP. However, feeding birds SDBP improved FCR six weeks after the induced acute stress (Figure 2). Improvement was observed at six wk, where the birds fed with SDBP had a lower FCR, SDBP1 (1.901), and SDBP2 (1.975) than birds in the control treatment (2.041). However, no differences were observed at 12 wk. Therefore, improvement in FCR did not persist after the SDBP was removed from the feed (G2 and F1). Campbell et al. (2006) reported effects on feed efficiency in broiler performance where birds were in a challenged environment. The SDBP plasma was fed in granular form and powder form. They were also fed for two different periods: 0-14 days and 0-35 days. The benefit was observed for both periods. Therefore, SDBP may need to be fed continuously for full advantage to the animal.

No significant differences were observed for carcass or parts yield due to treatments (Table 6). In experiments conducted by Henn et al. (2013), there was no effect due to the inclusion of SDBP in starter and grower diets regarding carcass or parts yields in 42-day-old broilers. However, Bregendahl et al. (2005) reported that broilers fed SDBP had higher carcass weights and increased breast meat yield. No significant differences were found in cut-up yields of legs or the remainder of the carcass.

Plasma corticosterone levels were measured pre-stress, 1 d post-stress, and 3 wk post-stress (Table 7). There was a time-diet response for plasma CORT. No differences were observed among treatments for pre-stress blood sampling. However, an increased CORT level from pre to post-stress was observed in all three treatment groups. In addition, there were differences ($p<0.05$) in the corticosterone levels by treatment immediately post-stress. In the SDBP1 (23.815 ng/mL) treatment, the turkeys had a significantly higher plasma CORT level than the control-fed birds (16.402 ng/mL). Turkeys fed the SDBP2 diet (19.17 ng/mL) were intermediate in plasma CORT levels compared to the control and SDBP1 treatment groups.

Interestingly, the turkeys among the three treatment groups at the 3 wk post-stress sampling time

Table 6: Effect of feeding spray-dried bovine plasma (SDBP) on 12 weeks old female turkey carcass and parts yield.

Diet	Live weight (kg)	Hot carcass %	Cold carcass carcass %	Thigh %	Drums %	Wings %	Breast skin %	Breast major %	Breast minor %	Breast rack %
Control	6.80	78.02	80.08	16.47	12.96	12.35	1.98	20.37	5.83	29.47
SDBP[1]	6.75	78.17	80.01	16.23	13.01	12.41	2.08	20.66	5.81	29.44
SDBP[2]	6.77	77.85	79.6	16.47	13.02	12.6	2.04	19.94	5.48	29.80
SEM	0.07	0.64	0.29	0.17	0.13	0.12	0.73	0.34	0.17	0.54
P-value	0.91	0.24	0.47	0.30	0.94	0.35	0.33	0.33	0.33	0.87

[1]SDBP at 1% of the diet
[2]SDBP at 2% of the diet

Table 7: Effect of exposure to a cold episode and feed and water withholding for 24 hours in turkey hens fed spray-dried bovine plasma (SDBP) on plasma corticosterone (ng/mL).

Diet		Prestress	Post-Stress (1d)	Post-Stress (3 wk)
Control		8.224	16.402[b]	2.915
SDBP1[1]		6.642	23.815[a]	3.071
SDBP2[2]		6.436	19.170[ab]	2.942
Mean		7.101[y]	19.796[x]	2.976[z]
SEM		1.247	2.000	0.498
P-value		0.545	0.039	0.972
Diet	0.199			
Day	0.0001			
Diet*Day	0.030			

[1]SDBP at 1% of the diet.
[2]SDBP at 2% of the diet.
[a,b]Means within a column lacking a common superscript differ ($P \leq 0.05$).
[x,y,z]Means within a row lacking a common superscript differ ($P < 0.05$).

Table 8: Influence of supplemented dietary spray-dried bovine plasma (SDBP) on hen turkey immune organs (%).

Diet	Bursa	Spleen	Thymus
Control	0.119	0.128	0.052
SDBP1[1]	0.110	0.138	0.059
SDBP2[2]	0.105	0.127	0.059
SEM	0.008	0.007	0.004
P-value	0.484	0.524	0.454

[1]SDBP at 1% of the diet.

[2]SDBP at 2% of the diet.

had plasma corticosterone levels that were significantly lower than those found in the pre-stress turkeys. It has been reported that plasma corticosterone levels are elevated in young poults and that those levels can decline over time (McCorkle et al., 1985). Carroll et al. (2002) observed an increase in the activation of the hypothalamic-pituitary-adrenal (HPA) axis after being exposed to a lipopolysaccharide (LPS) challenge in weaned pigs in comparison to pigs fed a diet that did not contain SDBP. The authors suggested that there may have been two potential mechanisms by which SDBP prevented the activation of the HPA axis. In the case of the mentioned study, one is a direct effect of SDBP in preventing antigen growth in the small intestine, and the second is an indirect effect, helping the pig's mucosal integrity. These mechanisms may have worked to reduce and activate the pig's HPA axis by reducing immunological challenges. Since the adrenal glucocorticoids are associated with adaptive responses in animals exposed to stressors. It is possible that the supplementary SDBP had imparted some protective advantage to those turkeys compared to the controls.

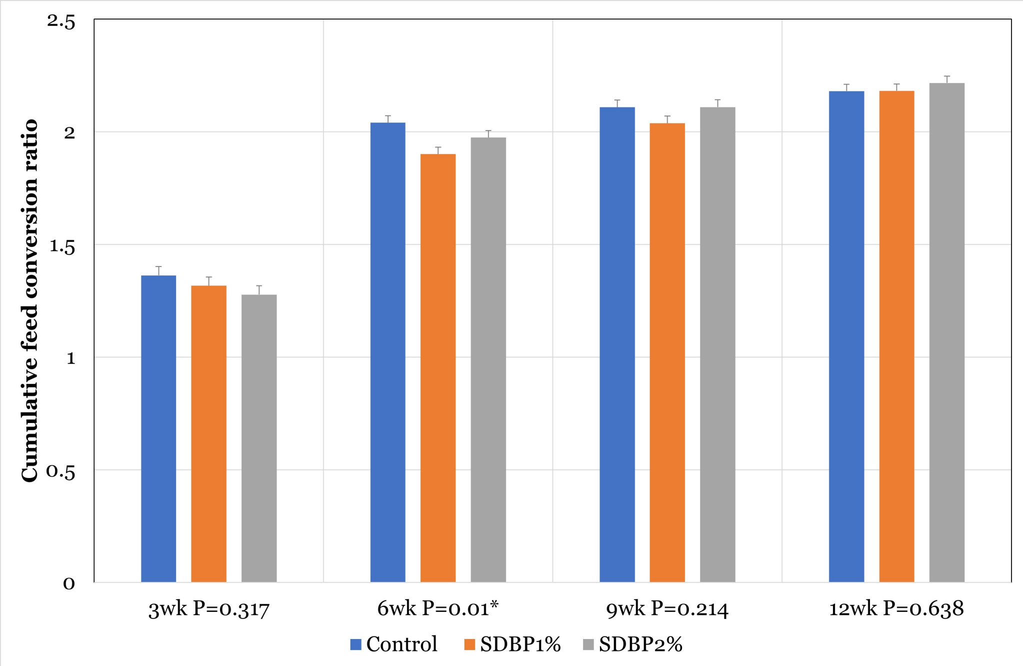

Figure 2: Cumulative feed conversion ratio (corrected for mortality) of hen turkey poults fed dietary spray-dried bovine plasma (SDBP).

Table 9: Effect of dietary spray-dried bovine plasma (SDBP) on hen turkey tibia measurements.

Diet	Bone Strength (Newtons)	Bone Strength (pound-force)	Elasticity (g/sec)	Bone Length (mm)	Bone Diameter (mm)	Ash %
Control	778.00	174.90	3353.97	180.90	13.35	19.59
SDBP1[1]	789.55	177.5	3590.56	182.79	13.61	19.77
SDBP2[2]	809.43	182.0	3495.68	178.63	13.49	19.82
SEM	35.81	8.05	155.33	2.73	0.292	0.253
P-value	0.82	0.82	0.56	0.56	0.81	0.80

[1]SDBP at 1% of the diet
[2]SDBP at 2% of the diet

Based on these data, it is suggestive that SDBP promotes adaptive actions when turkeys are subjected to a strong stressor. It has been noted above that strong stressors appear to be necessary to maximize the adaptive responses of birds, cattle, and swine, which have been supplemented with SDBP. Because the stressor placed on turkeys in the study herein were acute and short-duration, the induced adrenal cortical response may have been short-lived. Consequently, the full effect of the long-term adaptive response was not activated, which may partially explain why post-stress perturbations in development were not observed. In addition, in this study, the benefit of the SDBP may have ceased due to it only being fed for the first 6 wk of the trial.

Organ weights from the bursa, spleen, and thymus were also measured at 12 wk. No significant differences were observed between the SDBP-fed and control-fed turkeys (Table 8). However, it is possible for any kind of stressor to serve as a starting point for any malfunction in the bird's multiple organ systems, including the bird's whole body (Mailyan, 2019).

Regarding bone health, the right tibia was used for all parameters (Table 9) in 12 wk old turkey hens. Bone ash percentage was measured using the initial weight of the bone and comparing it to the final weight of ash content. For bone ash percentage (%), no statistical differences were observed among dietary treatments. The lack of differences in bone ash suggests that there were no effects on skeletal growth and development due to feeding SDBP to turkeys for the initial six wks. There were no significant differences observed due to SDBP treatment for tibia bone-breaking strength or the Newton/pound-force needed to break the bone. No difference was observed in bone elasticity, which measures the elastic modulus of the bone. The elastic modulus of the bone gives the measure of the resistance offered by the bone to elastic deformations when exposed to external stress, such as the Newtons of force exerted to break the bone. Finally, no differences were observed among treatments for bone length or bone diameter.

Conclusion

The model used in this study simulating less than optimal brooding conditions and potential conditions experienced by turkeys during transportation from brooder to rearing facilities successfully elicited both a performance and a corticosterone response. This was observed with bird behavior and their reaction to the induced stress via plasma corticosterone levels which increased from pre to post-stress. While birds gained weight throughout the experiment, they underperformed compared to commercial breeder standards. There were no statistical differences due to SDBP inclusion up to 2% for most of the performance parameters. Corticosterone levels were increased by dietary % SDBP supplementation, which agrees with data reported for swine, where cortisol increased when pigs were challenged and fed SDBP. However, SDBP, such as feed in this study, may need to be provided continuously for the full benefit of the animal. Further research needs to be conducted in turkey production under different stress environments and different levels and lengths of SDBP inclusion.

Based on this work, there was a significant turkey hen plasma corticosterone response to SDBP when included in the feed when the birds were exposed to rearing and managemental stressors. However, SDBP may need to be fed continuously during rearing for full benefit to the animal Further research is needed in turkey production under different stress-induced environments and different levels and lengths of SDBP inclusion.

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