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Comparing the Production Performance of Turkey Hens on Organic Versus Antibiotic Free Feed

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ABSTRACT

The rise in consumer demand for organic poultry has shifted producer focus towards maximizing production efficiency in organic-fed birds. Due to the restrictions on synthetic methionine in organic poultry diets, birds fed a U.S. commercial poultry diet are at risk for methionine deficiency. This can result in decreased bird weight and feed efficiency as well as increased fat deposition. Methionine deficiency in commercial turkeys is not well-documented. To bridge this gap in knowledge, this study was performed to evaluate the performance of turkey hens on an organic diet. Starting on day of hatch, 448 Nicholas Select turkey hens were raised until processing on day 105. From day 14 to day 105, hens were provided either a commercial antibiotic free diet or an organic diet. To remove deficiencies in amino acids other than methionine as a confounding variable, the organic diet was formulated with more dietary protein but still contained less dietary methionine. Each treatment had eight repetitions with 28 hens per repetition in a randomized complete block design. All hens were weighed individually on days 14, 42, 70, and 105. Feed consumption and final processing yields were also recorded. Hens fed the organic diet had higher average live bird weights than the hens fed the antibiotic free diet, but they also had a greater feed intake. After evisceration, there was no significant difference between carcass and breast weights of each treatment. Therefore, the excess protein contributed to overall bird weight but did not result in more marketable meat. It is likely that methionine deficiency interfered with lipid transport pathways and deposited excess nutrients as fat. Overall, organic-fed turkey hens can perform at the level of antibiotic free-fed hens but at the expense of higher feed prices and greater feed consumption.

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LIST OF ABBREVIATIONS

AA	Amino acid
ABF	Antibiotic free
CAT	Catalase
D	Day
FCR	Feed conversion ratio
GLM	General linear model
GSH	Glutathione
GSH-Px	Glutathione peroxidase
LSD	Least significant difference
MDA	Malondialdehyde
NIR	Near-infrared spectroscopy
SEM	Standard error of the mean
SOD	Superoxide dismutase
TSAA	Total sulfur amino acids

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When I started my Penn State and Schreyer journey, I was daunted by the honors thesis and the prospect of tackling such a large project alone. However, I soon learned that with the support of some amazing and knowledgeable people, anything is possible. Firstly, I would like to thank Dr. Boney for providing me with the opportunity to lead this study and guidance during the research and writing process. Thank you to Dr. Staniar for serving as my thesis advisor and reader. The manual labor of this study would not have been possible without the assistance of graduate students and undergraduate research assistants in Dr. Boney's lab and the staff of PERC. Special thanks to Courtney Poholsky for generous guidance and Brendan Liebross for managing the first portion of the study. Thank you to my family for moral support and my friends for being thesis writing companions. When it came to selecting my thesis topic, it seems only fitting that I unintentionally followed in the footsteps of the first agricultural Penn Stater in my family. My great-grandfather, Roger Latham, was a renowned researcher of wild turkeys and received his Ph.D. at Penn State. With this thesis, I hope that I have made his legacy and those who have stood behind me proud.

Chapter 1

Literature Review

1.1 Introduction

1.1.1 Biological Function and Absorption of Methionine

Methionine is an essential sulfur-containing amino acid that is crucial to include in the diet of commercial poultry. It supports protein synthesis, immune function, feather growth, and antioxidant function. On a molecular level, methionine serves as a methyl donor group and sulfur donor (Bunchasak, 2009). L-methionine is also a precursor of L-cysteine, a key amino acid in maintaining protein biosynthesis (Park et al., 2018). Absorption of methionine from the diet occurs in the small intestine. Transport is mediated via a variety of pathways such as Na+ dependent mechanisms and cationic amino acid interactions (Bunchasak, 2009).

1.1.2 Methionine Deficiency

Methionine deficiency is defined as insufficient supplementation of the amino acid methionine in the diet, either through limitations of quantity or bioavailability. Soybean meal, which is low in methionine, is one of the most common protein sources for amino acids in U.S. commercial poultry diets (Park et al., 2018). As a result, methionine is the first limiting amino acid in typical soybean and corn poultry diets and therefore creates the most limitations on potential bird growth and production. The exact methionine requirement levels are widely debated for poultry due to the difficulties of calculating separate requirements for the total sulfur amino acids (TSAA), methionine and cysteine. The importance of TSAA in poultry diets has resulted in extensive research on both chickens and turkeys for estimated requirements. The starter requirement is set at 0.55% for methionine alone and 1.1% for TSAA as percentages of the diet for turkeys (National Research Council, 1994). Methionine levels in the diet below those recommended by the NRC would be considered deficient from a production standpoint, although the commercial use is often greater than the minimum levels. Imbalances with other amino acids can exacerbate the effects of deficiency. Coupled with an excess of cysteine, chicks fed a methionine-deficient diet experienced growth depression and impairment of methionine analog utilization (Baker, 2009).

1.1.3 Organic Poultry Production

Poultry producers most often utilize synthetic methionine supplementation in the diet to support the natural methionine found in protein sources. However, concern for adequate methionine supplement has increased with the recent popularity of organic poultry. Organic markets are a rising point of interest in poultry production with potential for higher economic gains. This is due to increasing consumer demand for meat raised without synthetic additives. An assessment of public opinion in the U.S. in 2005 has found that consumers would be willing to pay a 20-30% premium for organic foods (Gifford et al., 2005). A later study performed in 2011 has shown that this willingness has increased over time, likely due to societal shift towards less artificial chemicals in food. Consumers have now expressed that they would pay a 35% premium for general organic label chicken breast and a 104% premium for USDA certified organic labels (Van Loo et al., 2011). Even though consumers have expressed an intention to buy organic goods, improving the efficiency of the birds to maintain desirable prices is crucial for profit. In order to achieve the potential for a higher rate of return for an organic bird, producers must also follow organic market regulations. Organic poultry is defined by strict synthetic diet and facility regulations. The USDA had initially determined that no synthetic amino acid supplementation is permitted in organic poultry diets. However, methionine has such a crucial role in supporting production performance that stipulations were created to allow for a small lifetime supplementation of synthetic methionine (Fanatico et al., 2009). Organic markets limit synthetic methionine in the diet to 3 pounds per ton, which is equivalent to 0.15% of the total diet. With such a small portion of supplemented methionine permitted in the diet, methionine deficiency is a major concern. The intention for such a low allowance is to slightly offset the need for excess crude protein while balancing consumer desires for low synthetic inclusions, but the result is often accepting deficiency or spending extra for more protein. Antibiotic use past one day of age is also not permitted in poultry sold as organic (Fanatico et al., 2009). This increases disease risk for birds since methionine is also important for immunological function. As long as protein sources are free of certain preservatives, organic forms of methionine such as fish meals are permitted. These alternatives tend to come with their own costs and environmental considerations. With economic potential in organic markets and desire for poultry producers to maximize protein output in their meat poultry, it is important to understand mechanisms behind methionine deficiency and how to prevent it. This literature review will evaluate methionine deficiency effects on production parameters and metabolic function in poultry and discuss methods of diagnosis, treatment, and prevention.

1.2 Pathology of Methionine Deficiency

1.2.1 Oxidative Stress and Apoptosis

Oxidative stress is the result of reactive oxygen species buildup within the body. Antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) work to decompose reactive species such as hydrogen peroxide (Ruan et al., 2018). Methionine is a key antioxidant factor to protect intestinal mucosa from reactive oxygen species by activating these antioxidant enzymes. When broilers were provided a methionine deficient diet defined as 0.26-0.28% methionine and 0.50-0.62% methionine plus cysteine, there was a decrease in SOD, CAT, and GSH-Px activity (Ruan et al., 2018). Glutathione (GSH), a biomarker for oxidative stress and co-substrate for GSH-Px to maintain oxidative balance, also experienced a decrease in activity (Ruan et al., 2018). Malondialdehyde (MDA), a molecule that serves as an indicator of lipid peroxide accumulation, was higher in the methionine deficient group and suggests an increase in oxidative stress (Ruan et al., 2018). A similar study found the same effects on SOD, GSH-Px, CAT, GSH, and MDA levels when methionine deficient, but in the liver and kidney (Song et al., 2021). Buildup of reactive oxygen species impairs intestinal immunity and affects signaling pathways to promote apoptosis. Therefore, methionine deficient groups of broilers demonstrated higher percentages of apoptotic cells in the small intestine (Ruan et al., 2018).

1.2.2 Immunity

Methionine plays a key role in immunity in poultry, and therefore its deficiency can have detrimental effects on the health of the bird. Specifically, birds that were methionine deficient

(0.22-0.24% methionine) displayed a suppression of mucosal immunity as B cell expression decreased (Song et al., 2021). Deficiencies have led to immune organs dysplasia and decreases in size of the spleen, thymus, and bursa of Fabricius. These effects are theorized by suggesting that methionine serves as an immune regulatory factor or hormone regulator. As a methyl group donor, methionine also can regulate gene expression and specifically immune-related genes (Ruan, 2017).

1.2.3 Fat Deposition

Fat deposition is an important consideration for poultry producers as higher protein content is more desirable to consumers. Methionine is important for lipid metabolism regulation. Increased fat deposition and decreased fatty acid transportation were reported in Pekin ducks fed methionine-deficient diets (Wu et al., 2022). In poultry, fat is synthesized mainly in liver and transported via low-density lipoprotein cholesterol (LDLC). Methionine deficiency caused an increase in serum triglyceride (TG) and non-esterified fatty acid (NEFA) and decreased total cholesterol and LDLC (Wu et al., 2022). Methionine-deficient Pekin ducks also demonstrated decreased albumin expression in liver and lipolytic genes and proteins in abdominal fat, which impaired fatty acid transport and caused excessive fat deposition. Since albumin works to transport fatty acid in blood, decreased expression results in fat deposition (Wu et al., 2022). The methionine deficient Pekin ducks experienced an increase in subcutaneous and abdominal fat (Wu et al., 2022). Similarly, the impact of methionine on fatty acid transportation has resulted in greater fat deposits in broiler chicks (Sekiz et al., 1975). These results suggest that methionine deficiency causes increased adipogenesis and decreased lipolysis, contributing to accumulation of fat within the body.

1.2.4 Energy Utilization

When poultry is fed a diet deficient in an essential nutrient, they will display an increase in feed intake to compensate for the deficiency (Wu et al., 2022). However, there is still a decrease in average daily gain despite the increased consumption (Wu et al., 2022). The effects of methionine on intake and average daily gain depend on the severity of the deficiency. A slight deficiency will result in consumption of more feed but no significant body weight gain (Sekiz et al., 1975). Mechanisms of ATP production are suspected to be supported by methionine which indicates that its deficiency causes inhibited growth (Wu et al., 2022). It is theorized that the extra food is not contributing to an increase in average daily gain because of decreased digestibility, net energy yield, increased heat, or greater storage of energy in form of adipose tissue (Sekiz et al., 1975). This disparity between increased feed consumption and lack of increase in weight gain results in decreased feed utilization (Sekiz et al., 1975). When methionine was added to diets of initially deficient ducks, feed conversion ratio and average daily gain were restored (Wu et al., 2022). Studies have shown that higher levels of methionine are needed for maximum food utilization compared to maximum growth (Sekiz et al., 1975). Methionine supplementation does reach a certain threshold in which growth plateaus despite increased quantities in the diet (Sekiz et al., 1975).

1.3 Diagnosis of Methionine Deficiency

1.3.1 Production Parameters

When considering methionine deficiency, producers may first notice changes in standard production parameters for their flock. Methionine deficient birds will display increased feed intake, decreased average daily gain, and decreased energy utilization as determined by feed conversion ratio (Wu et al., 2022). Birds during processing will also have higher levels of fat deposition (Wu et al., 2022). While these signs are not exclusive to methionine deficiency, they can direct a producer towards it as a possible cause.

1.3.2 Feather Picking

When the birds are lacking in methionine, they have been shown to consume excess feed to compensate (Sekiz et al., 1975). Birds will also find a more concentrated form of methionine that is readily available to them: feathers. Feathers contain homocysteine, a derivative of methionine. Methionine deficiency can result in increased feather picking to consume the homocysteine (Burley et al., 2016). This can be observed in poultry houses as bare and bloodied birds and potentially increased mortality rates, although increased rates of mortality due to methionine deficiency have not been proven via research.

1.3.3 Test Supplementation

If a methionine deficiency is the cause of health issues in the bird, then studies have shown that supplementing methionine at sufficient quantities will alleviate the effects (Wu et al., 2022). Large-scale poultry operations can select a test diet with only methionine as the variable ingredient and evaluate production parameters and picking behaviors to see if effects are lessened or eliminated.

1.4 Treatment and Prevention of Methionine Deficiency

Both treatment and prevention of methionine deficiency can be achieved through sufficient supplementation of methionine into the diet. As an amino acid, methionine is contained within the protein sources in the diet. However, the most common protein source in poultry diets is methionine-deficient soybean (Park et al., 2018). Therefore, synthetic supplementation is most often relied upon by poultry producers to treat and prevent methionine deficiency. Sufficient methionine in bioavailable forms will prevent deficiency, and supplementation after a period of deficiency has been shown to ameliorate effects (Wu et al., 2022).

1.4.1 Bioavailability of Methionine Isomers

Methionine forms added to the diet must be bioavailable to the bird for proper treatment and prevention. Methionine exists in two natural isomers: L-methionine and D-methionine. Birds can only directly utilize the L-methionine isomer. Therefore, D-methionine must be converted to a bioavailable form. While less efficient than pure L-methionine supplementation, birds can convert D-methionine to L-methionine utilizing D-amino acid oxidase and transaminases (Zhang et al., 2015). A mix of both isomers in the form of synthetic DL-methionine is most widely used in the industry since both forms can be eventually utilized by the bird for a reduced overall cost

(Dibner and Knight, 1984). The molecule 2-hydroxy-4(methylthio)butanoic acid (HMTBA) is a synthetic precursor to methionine that proves comparable results in commercial production to DL-methionine (Zhang et al., 2015). However, exclusive L-methionine supplementation has been proven to be better utilized in turkey poults (Park et al., 2018). Having the more bioavailable form of methionine readily supplied to the bird is also important for improving redox status. Absorption of methionine from the gastrointestinal tract is considered the first pass for nutrients. If most of that methionine is bioavailable L-methionine, it can be immediately utilized to decrease lipid peroxidation by enhancing redox in the duodenum (Park et al., 2018). Therefore, birds should be provided synthetic L-methionine in the diet to treat an existing case of methionine deficiency or prevent the onset.

1.4.2 Organic Methionine Supplementation

In a conventional poultry operation, synthetic methionine can be added in any quantity necessary to prevent or treat a methionine deficiency. Complications arise when poultry are raised for organic markets. The USDA does not allow organic birds to consume any synthetic amino acids other than a small lifetime quantity of methionine (Burley et al., 2016). This quantity is below the needs of the bird and poses a risk factor for methionine deficiency. One possible solution is providing more sources of crude protein which would contain natural methionine. However, this would greatly increase feed costs. The elevated protein would also increase nitrogen content in the diet, creating environmental concerns as ammonia emissions would decrease poultry house air quality (Burley et al., 2016). The solution lies in supplementation of organic sources of methionine to the diet.

The most promising forms of organic supplementation are animal-based protein sources with higher methionine contents than the traditional soybean. One such source is menhaden-based fish meal, which has a 1.81% methionine content in comparison to 0.63% in soybean meal (Fanatico et al., 2018). Menhaden-based meal was tested against synthetically supplemented poultry and saw no noticeable differences in production performance while providing the organic methionine necessary for the organic market requirements. Similarly, carp-based meal has proven to be an adequate supplement. Carp-based meal utilizes bigheaded carp, which is an invasive fish species. It provides a methionine content comparable to the menhaden-based fish meal while also requiring a lesser cost (Upadhyaya et al., 2019). Insects, which have a methionine content of 2.32%, have also been tested in poultry diets and provided similar results to synthetic supplementation (Fanatico et al., 2018). Despite containing the most methionine out of the three sources, insects are difficult to source in the quantities necessary for the scale of poultry diet production. Fish meal is a promising method for the treatment and prevention of methionine deficiency in organic poultry but will need further testing for widespread commercial use.

1.5 Summary

Methionine is the most important amino acid for optimal production performance and metabolic function in commercial poultry. It acts as an important regulator for antioxidant enzymes and regulates immune function. Methionine deficiency causes increased oxidative stress, apoptosis, and fat deposition. It also decreases weight gain, energy utilization, and feed efficiency. Birds will display harmful feather picking to other birds in the house when a methionine deficiency is present, causing a detriment to bird health and well-being. The best treatment and prevention method is supplementing sufficient and bioavailable methionine into the diet. In organic poultry operations, using natural protein sources such as fish meal that are higher in methionine than the typical soybean meal diet can prevent deficiency. Further studies are necessary to determine specific parameters of methionine deficiency diagnosis on a larger scale and how the degree of methionine deficiency can impact diagnosis.

Chapter 2

Organic Versus Antibiotic Free Diets in Turkey Hens

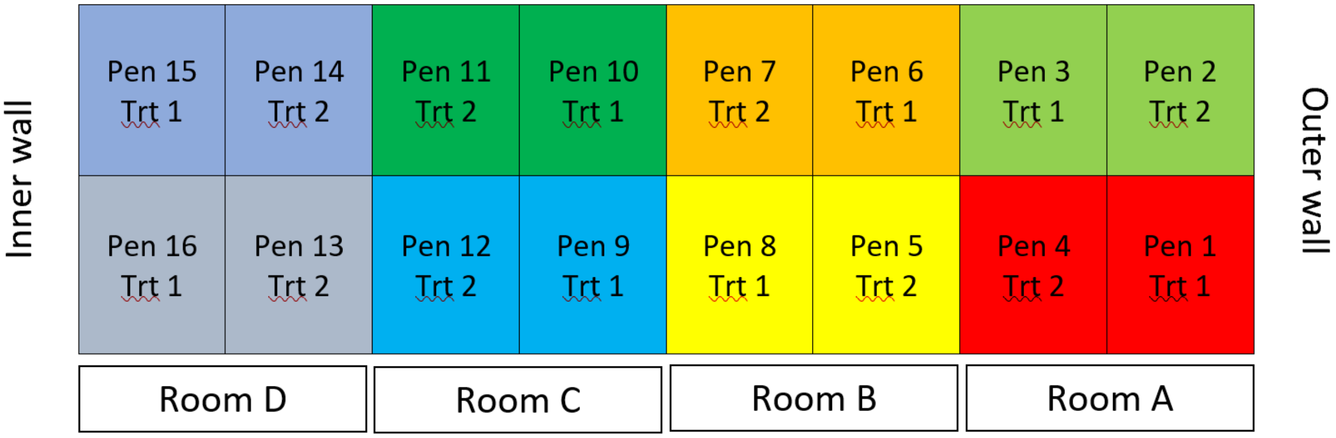
2.1 Introduction

In the past few decades, public perception of food production has created a demand for specialty goods. Consumers are becoming more concerned with the use of synthetic products in their food such as antibiotics and additives. Even feed provided to livestock is under scrutiny. When this demand is met, consumers are willing to pay premium prices. As a result, poultry producers are shifting towards the production of antibiotic free and organic birds. Antibiotic free birds are not permitted to receive antibiotics past one day of age. Organic birds are held to this standard as well as synthetic amino acid limitations in feed and facility regulations. With these amino acid limitations, producers are often forced to add excess crude protein to organic diets to prevent deficiency diseases. In the U.S. where soybean is the major protein source in poultry diets, methionine deficiency is of greatest concern. Methionine deficiency can result in decreased growth and feed efficiency as well as feather picking. Little research has been performed involving methionine deficiency in turkeys. Producers would benefit from knowing how organic-fed turkeys can perform in comparison to a commercial standard. Due to the excess protein in organic diets, producers must evaluate the financial costs of greater feed prices and the environmental cost of excess nitrogen excretion. The purpose of this study is to compare the performance of Nicholas Select turkey hens when feeding antibiotic free versus organic diets and to assess the cost-benefit of these diets for turkey producers. The statistical significance of differences in live weight gain, feed intake, average body weights, feed conversion ratio, mortality, and meat yield will be analyzed.

2.2 Materials and Methods

2.2.1 Experimental Design

This study was performed at Penn State University from August 1, 2022 - November 14, 2022. A total of 448 Nicholas Select turkey hens were obtained from a commercial hatchery on day of hatch (Aviagen Turkey in Harrisonburg, VA). Birds were evenly distributed in 16 floor pens with eight pens per treatment set up in a randomized complete block design, equating to 28 birds per pen (Figure 1). Pens were set up with closed water drinking, a free access hanging feeder, and pine shaving. Room temperature started at 34 °C and decreased by about 2 °C per week. A commercial lighting schedule was used with reductions in intensity on D71 and D74 to help control picking. Diet changes occurred on days 14, 42, 56, 70, and 84. Feed consumption was calculated at the end of each diet change. Live body weights of all birds were recorded on days 14, 42, 70, and 105. If toms were identified, they were marked as a mortality and removed from the remainder of the study. This experiment was reviewed and approved by The Pennsylvania State University Institutional Animal Care and Use Committee (PROTO202202274).



Inner wall									Outer wall
	Pen 15 Trt 1	Pen 14 Trt 2	Pen 11 Trt 2	Pen 10 Trt 1	Pen 7 Trt 2	Pen 6 Trt 1	Pen 3 Trt 1	Pen 2 Trt 2	
	Pen 16 Trt 1	Pen 13 Trt 2	Pen 12 Trt 2	Pen 9 Trt 1	Pen 8 Trt 1	Pen 5 Trt 2	Pen 4 Trt 2	Pen 1 Trt 1	
	Room D		Room C		Room B		Room A		

Treatment (Trt) 1 = Organic

Treatment (Trt) 2 = ABF

Figure 1. Pen Layout of Organic vs. Antibiotic Free Study

2.2.2 Feed Formulation

Birds were fed a common antibiotic free starter feed labeled Starter 1 until day 14. Birds were fed either an antibiotic free feed regimen or organic feed starting on day 14. Birds were provided with five additional diet formulations for each treatment labeled Starter 2, Grower 1, Grower 2, Finisher 1, and Finisher 2. Formulations and nutrients can be found in Tables 1 and 2. Costs of feed can be found in Table 3. The antibiotic free diet was able to be formulated with ideal amino acid ratios using synthetic amino acids. The organic diet was formulated with more crude protein to attempt to match amino acid ratios, but the lack of permitted synthetic additions prevented ideal balance.

Table 1. Antibiotic Free Diet Formulations and Calculated Nutrients

Ingredients	**Feeding Phase**				
	Starter 2 (3-6 wks)	Grower 1 (7-8 wks)	Grower 2 (9-10 wks)	Finisher 1 (11-12 wks)	Finisher 2 (13-15 wks)
	(%)				
Soybean Meal	41.3	36.00	30.80	26.15	23.00
Corn	51.038	56.93	61.69	66.87	69.579
Soybean Oil	2.95	2.75	3.55	3.45	3.9
Deflourinated Phosphate	2.2	1.86	1.63	1.29	1.365
Limestone	0.85	0.85	0.80	0.80	0.8
Betaine	--	--	--	--	--
Mineral Premix	0.15	0.15	0.15	0.13	0.125
L-Methionine	0.43	0.38	0.32	0.28	0.24
Salt	0.11	0.12	0.13	0.14	0.145
Vitamin Premix	0.075	0.08	0.08	0.06	0.0625
Choline Chloride	0.05	0.05	0.05	0.05	0.05
Rovabio Excel AP10	0.05	0.05	0.05	0.05	0.05
Sodium Bicarbonate	0.045	0.09	0.11	0.15	0.13
Vitamin E	0.03	0.04	0.04	0.03	0.0305
Allzyme SSF	0.025	0.03	0.03	0.03	0.03
Agrimoss	0.405	0.03	0.03	0.03	0.025
L-Lysine, 78.8%	0.135	0.37	0.34	0.31	0.29
L-Threonine	0.112	0.11	0.09	0.08	0.065
L-Arginine	0.045	0.10	0.09	0.08	0.0785
L-Valine	-	0.04	0.04	0.04	0.035
Calculated Nutrients					
ME (kcal/kg)	3,056	3,105	3,205	3,255	3,306
Crude Protein (%)	24.20	21.96	19.75	17.84	16.49
Crude Fat (%)	5.71	5.53	6.36	6.33	6.80
Crude Fiber (%)	2.39	2.31	2.20	2.11	2.04
Ca (%)	1.37	1.24	1.14	1.00	1.01
Available P (%)	0.69	0.62	0.57	0.50	0.51
Ca:AvP	1.99:1	2:1	2:1	2:1	1.98:1
Sodium (%)	0.17	0.17	0.17	0.17	0.17
Chloride (%)	0.19	0.19	0.19	0.19	0.19
Phytase (FTU/kg)	500	500	500	500	500
Dig. Lysine (%)	1.50	1.34	1.19	1.06	0.97
AA Ratios to Dig. Lysine					
Arg	105	105	105	105	105
Ile	61	61	61	61	61
Met	48	48	48	48	47
TSAA	68	69	69	70	70
Thr	60	60	60	60	60
Val	68	69	70	71	72
Trp	17	17	17	17	17

Table 2. Organic Diet Formulations and Calculated Nutrients

Ingredients	Feeding Phase				
	Starter 2 (3-6 wks)	Grower 1 (7-8 wks)	Grower 2 (9-10 wks)	Finisher 1 (11-12 wks)	Finisher 2 (13-15 wks)
	(%)				
Soybean Meal	54.768	48.074	41.85	36.4	32.65
Corn	36.302	43.7295	49.659	55.817	59.262
Soybean Oil	5.0	4.6	5.2	4.95	5.25
Deflourinated Phosphate	2.095	1.765	1.545	1.205	1.29
Limestone	0.8	0.8	0.8	0.75	0.75
Betaine	0.33	0.25	0.15	0.08	0.02
Mineral Premix	0.15	0.15	0.15	0.125	0.125
L-Methionine	0.15	0.15	0.15	0.15	0.15
Salt	0.13	0.155	0.19	0.215	0.24
Vitamin Premix	0.075	0.075	0.075	0.0625	0.0625
Choline Chloride	0.05	0.05	0.05	0.05	0.05
Rovabio Excel AP10	0.05	0.05	0.05	0.05	0.05
Sodium Bicarbonate	0.045	0.06	0.04	0.06	0.015
Vitamin E	0.03	0.0365	0.0365	0.0305	0.0305
Allzyme SSF	0.025	0.03	0.03	0.03	0.03
Agrimoss	54.768	0.025	0.025	0.025	0.025
Calculated Nutrients					
ME (kcal/kg)	3,056	3,105	3,205	3,255	3,306
Crude Protein (%)	28.57	25.92	23.42	21.29	19.78
Crude Fat (%)	7.57	7.19	7.84	7.68	8.01
Crude Fiber (%)	2.61	2.54	2.41	2.31	2.22
Ca (%)	1.37	1.24	1.14	1.00	1.01
Available P (%)	0.69	0.62	0.57	0.50	0.51
Ca:AvP	1.99:1	2:1	2:1	2:1	1.98:1
Sodium (%)	0.17	0.17	0.17	0.17	0.17
Chloride (%)	0.19	0.19	0.19	0.19	0.19
Phytase (FTU/kg)	500	500	500	500	500
Dig. Lysine (%)	1.50	1.34	1.19	1.06	0.97
AA Ratios to Dig. Lysine					
Arg	123	123	124	125	125
Ile	76	76	77	78	78
Met	39	40	41	42	43
TSAA	68	69	69	70	70
Thr	63	64	65	66	67
Val	80	81	83	84	85
Trp	21	21	22	22	22

Table 3. Costs of Organic and Antibiotic Free Feed

Phase	Treatment	Price of Feed ($/per lb.)	Average Feed Intake (lb/hen)	Total Feed Costs per Hen ($)
Starter 2	Organic	0.369	6.847	2.526
	ABF	0.349	6.207	2.165
Grower 1 and 2	Organic	0.354	16.449	5.815
	ABF	0.337	15.898	5.358
Finisher 1 and 2	Organic	0.339	29.922	10.132
	ABF	0.327	29.304	9.568

2.2.3 Processing

On day 105 after final live weights were recorded, one bird from each pen was chosen via randomized selection to be processed. Birds were stunned with an electric knife and euthanized via exsanguination. Hot carcass yield was recorded after evisceration, and birds were chilled in an ice bath overnight. Chilled carcass, breast, tenderloin, thigh, drums, and wing weights were recorded. Yield percentages were calculated based on chilled carcass weights.

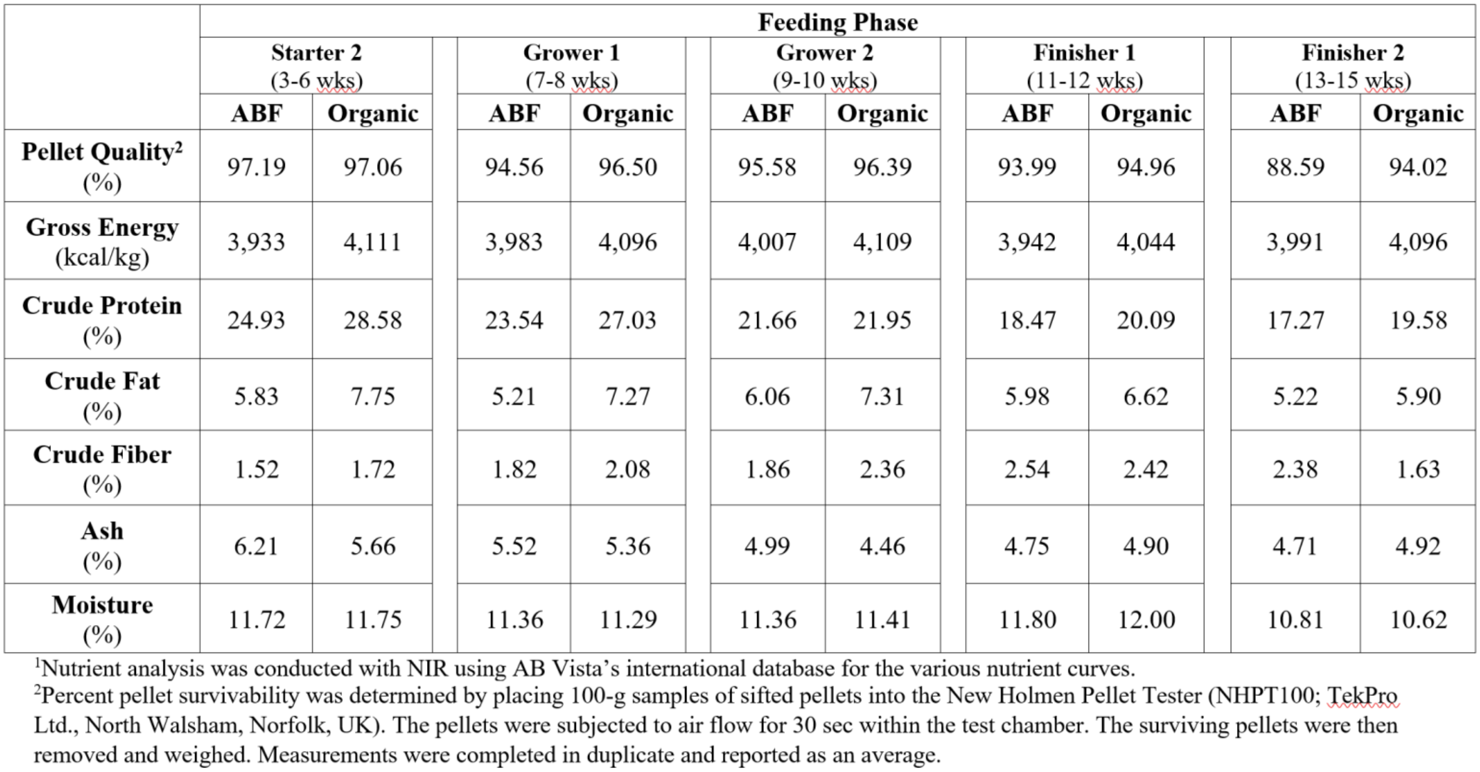
2.2.4 Statistical Analysis

An ANOVA was used to analyze data using GLM procedure of SAS 9.4. The experimental unit was one pen with 28 birds. Two treatments were analyzed with eight repetitions for each treatment. The treatments were arranged in a randomized complete block design.

2.2.5 Feed Analysis

Gross energy was calculated via bomb calorimeter. Nutrient analysis of crude protein, crude fat, crude fiber, ash, and moisture content was conducted via NIR using AB Vista's nutrient curve database. Pellet quality was determined using the New Holmen Pellet Tester. 100-g samples of pellets were sifted, placed in the tester, and surviving pellets were weighed. The results of feed analysis are found in Table 4.

Table 4. Physical and Chemical[1] Analysis of Feed



	Feeding Phase									
	Starter 2 (3-6 wks)		**Grower 1** (7-8 wks)		**Grower 2** (9-10 wks)		**Finisher 1** (11-12 wks)		**Finisher 2** (13-15 wks)	
	ABF	**Organic**	**ABF**	**Organic**	**ABF**	**Organic**	**ABF**	**Organic**	**ABF**	**Organic**
Pellet Quality[2] (%)	97.19	97.06	94.56	96.50	95.58	96.39	93.99	94.96	88.59	94.02
Gross Energy (kcal/kg)	3,933	4,111	3,983	4,096	4,007	4,109	3,942	4,044	3,991	4,096
Crude Protein (%)	24.93	28.58	23.54	27.03	21.66	21.95	18.47	20.09	17.27	19.58
Crude Fat (%)	5.83	7.75	5.21	7.27	6.06	7.31	5.98	6.62	5.22	5.90
Crude Fiber (%)	1.52	1.72	1.82	2.08	1.86	2.36	2.54	2.42	2.38	1.63
Ash (%)	6.21	5.66	5.52	5.36	4.99	4.46	4.75	4.90	4.71	4.92
Moisture (%)	11.72	11.75	11.36	11.29	11.36	11.41	11.80	12.00	10.81	10.62

[1] Nutrient analysis was conducted with NIR using AB Vista's international database for the various nutrient curves.

[2] Percent pellet survivability was determined by placing 100-g samples of sifted pellets into the New Holmen Pellet Tester (NHPT100; TekPro Ltd., North Walsham, Norfolk, UK). The pellets were subjected to air flow for 30 sec within the test chamber. The surviving pellets were then removed and weighed. Measurements were completed in duplicate and reported as an average.

2.3 Results and Discussion

2.3.1 Feed Intake

From D14-42, organic-fed hens consumed 290-g more feed per bird than the ABF-fed hens ($p < 0.001$; Table 4). From D14-70, organic-fed hens had a 550-g greater feed intake ($p = 0.016$; Table 6). The entire range of the study from D14-105 had a significant difference of 830-g more feed consumed by the organic-fed hens ($p = 0.023$; Table 9). No difference in feed intake was found from D42-70 ($p = 0.135$; Table 5), D70-105 ($p = 0.111$; Table 7), and D42-105 ($p = 0.089$; Table 8). Despite the organic feed having a greater gross energy and crude protein content, the excessive eating of the organic hens indicates that the organic diet contained a deficiency. The greater feed intake in the organic-fed turkey hens is consistent with Wu et al., 2022 as a method to compensate for insufficient methionine. In addition to more expensive feed, the difference in feed intake exacerbates the cost difference required to feed the organic hens from hatch to processing.

2.3.2 Live Weight Gain and Average Bird Weight

The difference in average live weight gain between organic-fed and ABF-fed hens was significant for almost every age range throughout the study with organic-fed birds having consistently higher weigh gain. From D14-42, the organic-fed hens gained an average of 270-g more live body weight per bird ($p < 0.001$; Table 4). From D14-70, organic birds had a 397-g greater live weight gain ($p = 0.001$; Table 6). From D70-105, organic-fed hens gained 281-g more weight ($p = 0.003$; Table 7). From D42-105, organic-fed hens had a 406-g greater live weight gain ($p = 0.001$; Table 8). The entire range of the study from D14-105 had a highly significant difference of 676-g more live weight gain per bird for organic-fed hens ($p < 0.0001$; Table 9). The difference in live weight gain from D42-70 was not significant ($p = 0.055$; Table 5). The difference in average bird weight between organic-fed and ABF-fed hens was significant for every weigh day throughout the study with organic-fed birds having consistently greater average bird weights (Figure 2). On D42, organic-fed birds weighed 272-g more ($p < 0.001$; Table 4). On D70, the organic-fed hens weighed 398-g more ($p = 0.001$; Tables 5-6). On D105, the final day of the study, the difference was highly significant at 676-g greater for organic-fed hens ($p < 0.0001$; Tables 7-9). This contrasts with Wu et al., 2022 which displayed a decreased average daily gain and decreased growth in methionine deficient birds despite increased feed intake. Since the organic diet contained more crude protein, this likely provided more nutrients for live weight gain and growth.

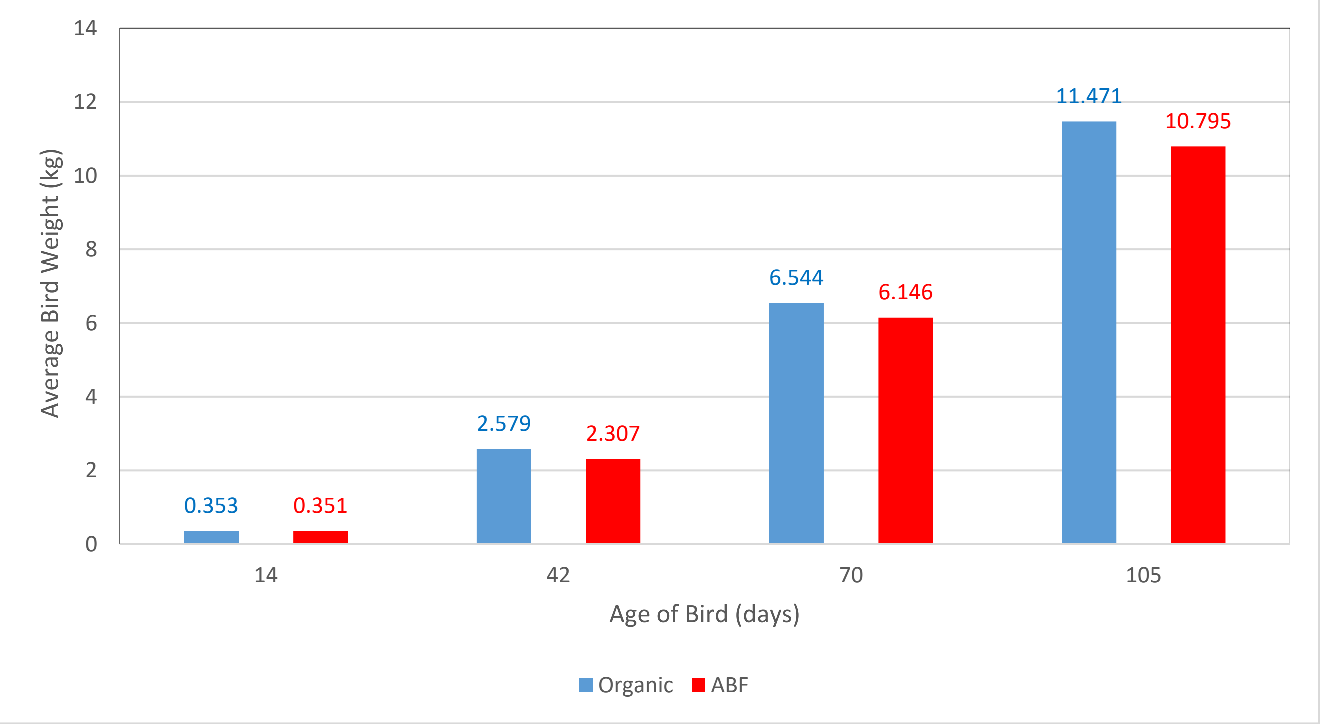


Figure 2. Comparison of Average Bird Weights Between Organic and Antibiotic Free Fed Turkey Hens at Each Weigh Day

2.3.4 Feed Conversion Ratio

Feed conversation ratio only displayed detectable differences in the range spanning the entire study. From D14-105, feed conversion ratio was 5.5 points higher in ABF-fed hens (p = 0.007; Table 9). The difference in feed conversation ratio from D14-42 (p = 0.075; Table 4), D42-70 (p = 0.234; Table 5), D14-70 (p = 0.240; Table 6), D70-105 (p = 0.050; Table 7), and D42-105 (p = 0.055; Table 8) was not significant. In Sekiz et al., 1975, decreased feed efficiency occurred as a result of increased consumption without significant weight gain. However, the organic-fed hens did experience increased weight gain and therefore had a lower feed conversion ratio.

2.3.5 Mortality

Mortality did not differ significantly in any range of the study. Throughout the study, multiple mortalities and culling occurred as a result of excessive feather picking. Sekiz et al. 1975 states that methionine-deficient birds are known to engage feather picking to potentially obtain homocysteine, a derivative of methionine. However, the overall mortality rate between the organic and ABF treatments did not significantly differ (p = 0.407; Table 9). This is consistent with the fact that this correlation has yet to be proven in research.

2.3.6 Processing Yields

In major processing parameters such as chilled carcass yield (p = 0.511), total white meat yield (p = 0.168), and breast yield (p = 0.359), no difference was detected (Table 10). Tenderloin yield was 9.5% higher in organic-fed hens (p = 0.018; Table 10). Thigh yield was 8.7% higher in organic-fed hens (p = 0.029; Table 10). Wing yield was 8% higher in ABF-fed hens (p = 0.003; Table 10). Drum yield was not significant (p = 0.457; Table 10). Despite having consistently greater average bird weights and live weight gain, the organic-fed hens did not have a significantly greater chilled carcass yield or breast yield. Wu et al., 2022 demonstrated that methionine-deficient poultry can have increased fat deposits as a result of decreased LDLC to transport fat out of the liver. The hens were eviscerated prior to measuring chilled carcass weight. The disparity between live weight differences and chilled carcass differences may suggest that visceral fat deposits contributed to higher live bird weights. Organic hens also had greater weight gain in the tenderloin and thighs to contribute to a greater weight. The only parameter in which the ABF-fed hens outperformed the organic-fed hens was wing yield at an 8% higher yield (p = 0.003). Growth of flight feathers stems from the wings. The development of primary and secondary flight feathers may require a higher methionine level than contour feathers. Methionine distributed from the diet to the wing area would be prioritized for the feathers over meat yield, creating a disadvantage for the organic-fed hens.

2.3.7 Cost Analysis

The total cost of feeding one hen from the Starter 2 phase until D105 processing on antibiotic free feed was $17.09. For organic-fed hens, the total cost for one hen was $18.47. This equates to a $1.38 difference in feed costs per hen. The significance of this difference increases with the volume of hens raised for processing. In this study, 448 hens resulted in a $309.12 difference in feed costs. Much larger productions with thousands of birds would experience a greater difference. While there are many costs for poultry production, feed is often the most significant. Even with the more expensive and nutrient-dense feed, the organic hens did not have significantly different chilled carcass or breast weights. While organic poultry can be sold for higher retail prices, producers must consider if the greater feed price and the additional costs of having an organic production make raising organic poultry cost effective.

Table 5. Turkey Hen Performance from D14-42

Treatment	Feed Intake (kg/bird)	Live Weight Gain (kg/bird)	D42 Avg. Bird Weight (kg)	FCR[1]	Mortality (%)
Organic	3.105^a	2.225^a	2.579^a	1.204	0.00
ABF	2.815^b	1.955^b	2.307^b	1.217	0.89
P-Value	<0.001	<0.001	<0.001	0.075	0.170
LSD	0.083	0.061	0.063	0.015	1.38
SEM	0.024	0.018	0.019	0.004	0.41

[1] Mortality corrected FCR: mFCR= FI/(LWG + Wt of Mortality)

$^{a\text{-}b}$ Values within comparisons with different superscripts differ ($P \leq 0.05$)

Table 6. Turkey Hen Performance from D42-70

Treatment	Feed Intake (kg/bird)	Live Weight Gain (kg/bird)	D70 Avg. Bird Weight (kg)	FCR[1]	Mortality (%)
Organic	7.46	3.965	6.544^a	1.883	2.68
ABF	7.21	3.841	6.146^b	1.863	2.71
P-Value	0.135	0.055	0.001	0.234	0.984
LSD	0.36	0.127	0.155	0.036	3.93
SEM	0.11	0.038	0.046	0.011	1.18

[1] Mortality corrected FCR: mFCR= FI/(LWG + Wt of Mortality)

$^{a\text{-}b}$ Values within comparisons with different superscripts differ ($P \leq 0.05$)

Table 7. Turkey Hen Performance from D14-70

Treatment	Feed Intake (kg/bird)	Live Weight Gain (kg/bird)	D70 Avg. Bird Weight (kg)	FCR[1]	Mortality (%)
Organic	10.57^{a}	6.191^{a}	6.544^{a}	1.706	2.68
ABF	10.02^{b}	5.794^{b}	6.146^{b}	1.716	3.57
P-Value	0.016	0.001	0.001	0.240	0.626
LSD	0.41	0.160	0.153	0.018	4.14
SEM	0.12	0.048	0.046	0.006	1.24

[1] Mortality corrected FCR: mFCR= FI/(LWG + Wt of Mortality)

[a-b] Values within comparisons with different superscripts differ ($P \leq 0.05$)

Table 8. Turkey Hen Performance from D70-105

Treatment	Feed Intake (kg/bird)	Live Weight Gain (kg/bird)	D105 Avg. Bird Weight (kg)	FCR[1]	Mortality (%)
Organic	13.57	4.929^{a}	11.471^{a}	2.768	5.11
ABF	13.29	4.648^{b}	10.795^{b}	2.860	3.26
P-Value	0.111	0.003	<0.0001	0.050	0.165
LSD	0.37	0.154	0.212	0.093	2.82
SEM	0.11	0.046	0.059	0.028	0.84

[1] Mortality corrected FCR: mFCR= FI/(LWG + Wt of Mortality)

[a-b] Values within comparisons with different superscripts differ ($P \leq 0.05$)

Table 9. Turkey Hen Performance from D42-105

Treatment	Feed Intake (kg/bird)	Live Weight Gain (kg/bird)	D105 Avg. Bird Weight (kg)	FCR[1]	Mortality (%)
Organic	21.04	8.894^{a}	11.471^{a}	2.356	8.93
ABF	20.49	8.488^{b}	10.795^{b}	2.394	6.32
P-Value	0.089	0.001	<0.0001	0.055	0.208
LSD	0.65	0.186	0.212	0.039	4.46
SEM	0.19	0.061	0.059	0.012	1.33

[1] Mortality corrected FCR: mFCR= FI/(LWG + Wt of Mortality)

[a-b] Values within comparisons with different superscripts differ ($P \leq 0.05$)

Table 10. Turkey Hen Performance from D14-105

Treatment	Feed Intake (kg/bird)	Live Weight Gain (kg/bird)	D105 Avg. Bird Weight (kg)	FCR[1]	Mortality (%)
Organic	24.14[a]	11.119[a]	11.471[a]	2.155[b]	8.93
ABF	23.31[b]	10.443[b]	10.795[b]	2.210[a]	7.14
P-Value	0.023	<0.0001	<0.0001	0.007	0.407
LSD	0.68	0.215	0.212	0.034	4.79
SEM	0.20	0.058	0.059	0.010	1.43

[1] Mortality corrected FCR: mFCR= FI/(LWG + Wt of Mortality)

[a-b] Values within comparisons with different superscripts differ ($P \leq 0.05$)

Table 11. Turkey Hen Processing Yields on D105

Treatment	Live Weight (kg)	Hot Carcass Yield (%)	Chilled Carcass Yield (%)	Breast Yield (%)	Tenderloin Yield (%)	Total White Meat Yield[1] (%)	Thigh Yield (%)	Drum Yield (%)	Wing Yield (%)
Organic	11.580	80.36	82.12	25.63	6.33[a]	31.96	15.42[a]	12.83	10.30[b]
ABF	10.671	79.97	82.51	24.61	5.73[b]	30.34	14.08[b]	12.53	11.19[a]
P-Value	0.100	0.423	0.511	0.359	0.018	0.168	0.029	0.457	0.003
LSD	1.134	1.07	1.34	2.46	0.46	2.49	1.16	0.89	0.42
SEM	0.339	0.32	0.40	0.73	0.14	0.74	0.35	0.27	0.13

[1] Total White Meat Yield = ((Breast Wt + Tenderloin Wt)/Chilled Carcass Wt)*100

[a-b] Values within comparisons with different superscripts differ ($P \leq 0.05$)

2.4 Conclusions

This study was derived from a need to assess the performance capabilities of organic-fed turkeys. When considering cost efficiency, producers are evaluating parameters that cost them money and allow for gains. In turkeys, chilled carcass yield and breast yield offer the greatest monetary value on the market. Despite the organic hens having a greater weight gain, they did not have significantly greater yields of carcass and breast compared to the antibiotic free hens. The organic feed was more expensive and consumed in greater quantities but did not provide additional meat gains. Even with these limitations, the market may offer a premium for organic poultry that can make the additional costs worthwhile. It is up to producers to perform a cost-benefit analysis of their own organic operation to decide whether profits are desirable. Overall, organic turkey hens are capable of matching the performance of antibiotic free-fed hens if provided free access to more nutrient-dense feed.

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