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Research Article

Production of Broilers Fed Native Methionine from Sunflower Seed Meal and Cowpeas

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Abstract

Objective: To determine production measurements of broilers fed native methionine from sunflower seed meal (SFSM) and cowpeas (CP).

Material and Methods: Diet 1 (D1, a basal diet of corn and soybean meal containing 2g synthetic methionine/2.2 kg diet), D2 (D1 + 20% SFSM), D3 (D1 + 20% CP), D4 (basal diet without added methionine + 20% SFSM + 20% raw CP), and D5 (basal diet without added methionine + 20% SFSM + 20% heated CP) were fed as starter, grower, and finisher. Weekly feed consumption, weight, and feed conversion ratio from 5 treatments x 5 replications x 12 birds per replicate were analyzed as a completely randomized design ($P \leq 0.05$). External examinations and necropsies were performed on 5 broilers/replication.

Results and Discussion: At the end of the study, broilers fed D1 - D5 had statistically similar feed intake and weight gain. Final weights for D5 broilers were 83.4%, 81.8%, and 92.5% of D1 weights at each respective phase. FCR was statistically similar throughout all phases for all diets. Undigested lignocellulosic compounds in added ingredients possibly increased transit time resulting in observed diarrhea, lower weights for D4 and D5 broilers, and footpad damage for D2, D4, and D5. Necropsies revealed no internal abnormalities for broilers fed D1 – D5.

Conclusions and Applications: Future work should include assessment of carcass fat and ammonia in manure of broilers fed all diets. Use of herbs as sources of methionine needs further study.

Keywords: *Plant Based Diets; Indigestibility of Lignocellulosic Compounds; Organic and Traditional Broiler Diets*

Introduction

After growth in consumption of organic food in the 1970's and 1980's, organic practices were formally recognized as a food production system in the United States when the Organic Foods Production Act was established in 1990 [1]. To date, the Office of the Inspector General and the National Organic Standards Board (NOSB) of the Agricultural Marketing Service have postponed the final rule for regulations pertaining to organic livestock and poultry in the US [2]. For traditional and organic diets, the NOSB continues to allow use of synthetic methionine forms DL-Methionine, DL-Methionine-hydroxy analog, and DL-Methionine-hydroxy calcium analog in layer and broiler feeds at two pounds per US ton (0.907kg/907.185kg).

Methionine is considered the first limiting amino acid in plant based poultry diets; the requirement is 0.40% to 0.57% [3,4]. Methionine provides methyl groups involved in metabolic reactions, cell proliferation, and development; and it is a precursor for cysteine. Cannibalism, poor immune system development, low body weight, poor feathering, feather pecking, and poor carcass quality are due to lack of methionine in diets [5]. Organic corn and soy with synthetic methionine remain viable sources of energy and protein for organic broilers diets. However, having several combinations of plant based feedstuff to supply innate methionine in poultry diets will be of interest to the broiler industry if the use of synthetic methionine is no longer allowed. As noted by many researchers, organic or traditional diets in which only vegetables as feed sources for methionine are used may be difficult to produce [6].

Sunflower seed meal and cowpeas contain methionine

In reviews of plant based sources of native methionine, Foster (2017) and Foster *et al.* (2020) proposed the use of sunflower seed meal (SFSM) and cowpeas (CP, *Vigna unguiculata* L. Walp) - both grown in several parts of the world [7,8]. In their extensive review on the use of SFSM in poultry diets, Ditta and King (2017) noted that the nutritional quality of the meal varies greatly due to chemical, mechanical, and thermal treatments for oil extraction. A high quantity of lignocellulosic compounds and a complex protein structure may cause low digestibility and less than optimal utilization in young broilers [9]. However, Kocher *et al.* (2000) reported that SFSM can replace 100% of soybean meal with added lysine in spite of the high indigestible carbohydrate content [10].

CP are grown in Southeast Asia, Africa, Latin America, and in the southern US; they are consumed by humans and used for animal fodder [11,12]. Black-eyed peas, a CP classified as a bean, contains 0.28% to 0.34% methionine; this greater than in most legumes except for soybean [12-15]. An added advantage for the use of CP is that they contain antioxidants that may prevent deterioration of fat in broiler tissue during processing and storage [16].

CP have been assessed in poultry diets as a replacement for soybean meal and corn [17-20]. Researchers found that broiler diets supplemented with yellow-, green-, and brown-seeded peas at a ratio of 400g/kg of feed did not significantly change feed consumption [17]. There was, however, a detrimental effect on weight gain and the feed conversion ratio (FCR) without added protein and essential amino acids [17].

Indigestibility of CP may be caused by inhibitors, complex carbohydrates, and acids contained in peas [18,19]. Added enzymes increased digestibility of feed (with peas) and mixed results were reported [16,21]. Containing phytase, Natuphos® E for pigs and poultry, could be useful [22].

Investigators reported significant improvements in protein and starch digestibility after micronizing yellow-, green-, and brown-seeded peas [23]. Diets with micronized peas produced greater growth rates and increased FCR when compared to an untreated pea diet or the control containing wheat and soybean [23]. Also, autoclaving, fermentation, microwaving, and roasting have been used to increase digestibility of peas [20,24].

Bolin., *et al* (1946) suggested that needed growth factors for chicks could be supplied by Alaskan peas and soybean meal [25]. Results from diet formulations using these plant sources also suggested that combined SFSM and CP could supply adequate methionine in broiler diets [8,26]. Thus, in our present work, we compared production measurements for two organic SFSM-CP diets with native methionine to corn/soy diets containing added synthetic methionine.

Materials And Methods

Materials

Organic cowpeas were purchased from Sun Organic Farms (San Marcos, CA). Organic soybean oil was purchased from Edwards International Inc. (Braintree, MA). Dicalcium phosphate was obtained from Higby's Country Feed Store (Dixon, CA). All other ingredients were donated by Associated Feed and Supply Co. (Turlock, CA). One-day-old, unvaccinated Cobb 500 chicks were donated by Foster Farms (Livingston, CA).

Diets

CP in Diet 5 (D5, below) were placed on aluminum sheets and heated for 30 min at 120°C. All CP were ground before adding to diets. Only organic ingredients were used and all diets were formulated to meet the breeder's recommendations for Cobb 500 broilers [26-28].

Diet 1 (D1) was a basal diet of corn and soybean meal, subsequently replaced in D2 with 20% sunflower seed meal (SFSM) and in D3 with 20% CP (Tables 1-3). Synthetic methionine (2g/2.2 kg) was added to D1 - D3. Both diets 4 and 5 (D4 and D5**)** contained the basal diet + 20% SFSM + 20% CP that partially replaced corn and soybean meal. D4 contained raw CP and D5 contained heated CP; neither D4 nor D5 contained synthetic methionine (Tables 4 and 5). All diets were formulated and fed as starter (0 - 10 days), grower (11 - 21 days), and finisher (22 - 42 days). Triplicates samples of diets were analyzed for nutrient content (Table 6; ANR Laboratory, University of CA, Davis) and triplicate samples of D1, D4, and D5 were also analyzed for amino acid content (Table 7; Proteomics Laboratory, University of CA, Davis).

Starter	As Fed (kg)		
Ingredient	**Starter**	**Grower**	**Finisher**
Organic corn, yellow	48.12	55.10	58.29
Organic soybean meal	46.39	39.33	35.86
Organic soybean oil	1.80	2.10	2.72
Dicalcium phosphate	1.67	1.49	1.38
Limestone, ground	1.03	1.07	0.91
Salt	0.45	0.40	0.38
DL-methionine 99%	0.26	0.25	0.25
Vitamin/Mineral mix[2]	0.25	0.23	0.19

Table 1: *Diet 1 - Basal corn/soy with synthetic methionine[1].*

[1]2g/2.2 kg.

[2]Met NRC (1994) requirements.

Ingredient	As Fed (Kg)		
	Starter	**Grower**	**Finisher**
Organic soybean meal	37.70	39.11	47.19
Organic corn, yellow	33.41	31.81	23.83
Organic sunflower meal	20.00	20.00	20.00
Organic soybean oil	5.53	5.96	6.11
Dicalcium phosphate	1.41	1.23	1.13
Limestone, ground	1.05	1.08	0.94
Salt	0.45	0.40	0.38
Vitamin/Mineral mix [2]	0.25	0.25	0.25

Table 2: *Diet 2 - Basal diet + sunflower seed meal (20%) with synthetic methionine[1].*

[1]2g/2.2 kg.

[2] NRC (1994) requirements.

	As Fed (kg)		
Ingredient	**Starter**	**Grower**	**Finisher**
Organic soybean meal	38.4	31.34	27.87
Organic yellow corn	36.96	43.97	47.18
Organic black-eye peas	20.00	20.00	20.00
Dicalcium phosphate	1.60	1.42	1.30
Organic soybean oil	0.90	1.19	1.81
Limestone, ground	1.08	1.12	0.95
Salt	0.45	0.40	0.38
DL-methionine 99%	0.30	0.26	0.25
Vitamin/Mineral mix[2]	0.25	0.25	0.23
Choline chloride	0.027	0.014	-

Table 3: *Diet 3 - Basal diet + raw cowpeas (20%) with synthetic methionine[1].*

[1]2g/2.2 kg.

[2]Met NRC (1994) requirements.

	As Fed (kg)		
Ingredient	**Starter**	**Grower**	**Finisher**
Organic soybean meal	76.98	49.03	40.38
Organic yellow corn			9.41
Organic black-eye peas	8.00	20.00	20.00
Organic sunflower meal	5.76	20.00	20.00
Dicalcium phosphate	1.31	0.98	0.88
Organic soybean oil	6.27	7.66	7.74
Limestone, ground	0.96	0.98	0.92
Salt	0.45	0.40	0.38
DL-methionine 99%	0.30	0.26	0.25
Vitamin/Mineral mix 2[2]	0.25	0.25	0.25

Table 4: *Diet 4 - Basal diet + sunflower meal (20%) + raw cowpeas (20%)[1].*

[1]No synthetic methionine added.

[2]Met NRC (1994) requirements.

Experimental plan

Chicks were randomly placed in floor pens to accommodate 42-day-old birds at 2 ft^2/bird. The completely randomized design consisted of 5 treatments (D1 - D5) x 5 replications x 12 birds per replicate (n = 300 birds). Feed and water were provided *ad libitum*. Electric heating lamps and brooder rings (during week 1) were used to provide appropriate food, water, and heat. Weekly feed consumption was recorded and used to calculate daily consumption for each replicate. Each bird was weighed initially and on day 10, 21, and 42. Data for digestibility of diets was incomplete and could not be reported. Eternal examination and necropsies were performed on 5 broilers per

	As Fed (kg)		
Ingredient	Starter	Grower	Finisher
Organic soybean meal	76.98	49.03	40.38
Organic yellow corn			9.41
Organic black-eye peas, heated	8.00	20.00	20.00
Organic sunflower meal	5.76	20.00	20.00
Dicalcium phosphate	1.31	0.98	0.88
Organic soybean oil	6.27	7.66	7.74
Limestone, ground	0.96	0.98	0.92
Salt	0.45	0.40	0.38
DL-methionine 99%	0.30	0.26	0.25
Vitamin/Mineral mix[2]	0.25	0.25	0.25

Table 5: *Diet 5 - Basal diet + sunflower meal (20%) + 20% organic heated cowpeas[1].*

[1]No synthetic methionine added.

[2]Met NRC (1994) requirements.

replication (School of Veterinary Medicine, University of CA, Davis). The Institutional Animal Care and Use Committee at the University of CA, Davis approved the protocol for feeding, handling, and care of broilers.

Statistical analysis

Data for comparisons of feed intake, weight gain, final weight, and feed conversion across diets were conducted using R Studio with significance at $P \leq 0.05$ [29]. Figures were prepared using GraphPad Prism (30).

Results And Discussion

Nutrient content and amino acids

Table 6 shows the nutrient content of D1-D5 for each of the diet phases. Crude fat seemed lowest in D3 (Table 3) for all feeding phases. This was likely associated with the low percent of crude fat in CP (Table 6). Table 7 shows the amino acid content of D1, D4 and D5. While some amino acids were provided in high quantities; there were no amino acid imbalances [8].

Production measurements and necropsies

Mean feed intake by bird per day for each diet phase is shown in Figure 1. Broilers fed D4 and D5 had significantly reduced feed intake for starter and grower phases as compared to D1 (Figure 1). Compared to feed consumption of D1 in the starter phase, chicks fed D4 consumed 83.9% and those fed D5 consumed 83%. In the grower phase, D4 consumed 91.2% of feed compared to D1 and D5 consumed 91.1%. By the end of the third phase, broilers fed D1- D5 had statistically similar feed intake.

Weight gain of all broilers from all diets is shown in Figure 2. Weight gain followed the same pattern across feeding phases as feed intake. FCR was statistically similar across phases for all diets (Figure 3).

Final weights are shown in Figure 4. Broilers fed D4 and D5 had significantly lower weights for the starter and grower phases when compared to those fed D1 in the same phases. D4 broilers weighed 85.4% of the mean weight of D1 broilers in the starter phase and 85.1%

	%									
Phase	**Diet**	**DM**	**ADF**	**Total N**	**Protein**	**TDN**	**Crude Fat**	**Ash**	**Cellulose**	**Hemi-cellulose**
Starter	1	90.8	5.1	4.7	29.2	70.7	6.8	7.9	4.6	7.4
	2	92.0	8.7	4.2	26.5	68.2	11.5	8.2	6.8	7.7
	3	91.2	5.9	3.9	24.2	70.1	5.8	7.8	5.2	7.2
	4	92.6	7.7	5.6	34.9	69.0	12.2	8.2	6.6	6.5
	5	92.5	7.9	6.1	38.1	68.9	12.2	8.1	6.7	7.1
Grower	1	90.6	4.8	3.8	23.9	70.9	7.1	7.0	4.3	7.1
	2	91.9	8.3	3.8	23.9	68.6	12.2	7.1	6.4	7.9
	3	90.7	5.1	3.6	22.2	70.7	5.8	6.7	4.5	5.8
	4	93.4	10.3	5.2	32.6	67.2	13.4	8.1	8.0	7.8
	5	93.3	9.9	5.2	32.5	67.5	13.4	7.5	8.1	7.1
Finisher	1	90.3	4.4	3.5	21.6	71.2	7.6	6.7	4.0	7.2
	2	92.0	8.1	3.8	23.6	68.6	11.6	7.0	6.2	8.1
	3	90.9	5.2	3.7	23.2	70.6	6.2	6.2	4.5	6.2
	4	93.3	9.4	4.9	30.4	67.7	13.8	7.4	7.5	8.8
	5	93.7	9.8	4.7	29.6	67.5	13.5	6.9	7.8	9.1

Table 6: *Nutrient content of diets[1] by phase.*

[1]Diet D1 (control), basal diet of organic corn and soybean meal, replaced in D2 with 20% organic sunflower seed meal and in D3 with 20% organic cowpeas. D1, D2, and D3 contained synthetic methionine (2kg/2.2 kg). Both D4 and D5 contained 20% organic sunflower seed meal + 20% organic cowpeas that partially replaced corn and soybean meal. D4 contained raw cowpeas and D5 contained heated cowpeas.

of the mean weights of those fed D1 in the grower phase; however, weights were statistically similar for the finisher phase. Birds fed D5, had significantly lower weights for all diet phases compared to D1. Weights for broilers fed D5 were 83.4%, 81.8%, and 92.5% of D1 at each respective phase (Figure 4).

External examination by a blind scoring system revealed that footpad damage was rated highest for broilers fed D2, D4, and D5 as discussed below. Necropsies of six-week-old broilers across diets did not reveal any internal organ and muscle abnormalities. We assumed that production measurements across dietary phases were associated with indigestibility of lignocellulosic compounds in added ingredients as discussed below.

Indigestibility of lignocellulosic compounds and amino acids

According to Ditta and King (2018), diets containing 20% SFSM would likely contain more lignocellulosics than D1 [9]. As shown in table 7, the starter, grower, and finisher diets for D2, D4, and D5 contained more combined cellulose and hemicellulose than that for D1. Due to the highly complex structure of the lignocellulosic compounds in SFSM, enzymatic action producing simple sugars may not have occurred [31,32]. Undigested lignocellulosic compounds can lead to greater transit time in the gut, causing diarrhea and less weight gain [32, 33]. Lower live weights of broilers were likely associated with lower %fat in carcasses [34]. Analysis of lipid and oxidation of fatty acids in thigh meat from carcasses of broilers from the present study are underway.

	Starter					Grower					Finisher				
	Diets														
Amino Acid	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Asx	2.27	2.57	2.96	3.15	3.16	3.13	3.17	2.77	2.30	1.70	1.98	2.36	2.71	2.71	2.76
Thr	0.78	0.87	1.00	1.06	1.07	1.06	1.07	0.94	0.78	0.60	0.70	0.84	0.94	0.94	0.96
Ser	0.97	1.07	1.21	1.28	1.28	1.28	1.29	1.15	0.96	0.74	0.84	0.99	1.11	1.10	1.13
Glx	3.80	4.22	4.74	5.00	5.03	5.06	5.11	4.55	3.79	2.91	3.34	3.99	4.51	4.47	4.49
Pro	1.11	1.20	1.32	1.38	1.38	1.38	1.39	1.27	1.11	0.92	0.98	1.09	1.17	1.17	1.18
Gly	0.77	0.87	0.99	1.05	1.05	1.05	1.06	0.94	0.79	0.61	0.73	0.88	1.01	1.00	1.00
Ala	0.92	1.01	1.13	1.19	1.19	1.17	1.19	1.08	0.95	0.78	0.84	0.96	1.06	1.06	1.06
Val	0.89	1.00	1.15	1.23	1.23	1.23	1.24	1.10	0.93	0.71	0.83	0.99	1.13	1.14	1.13
Ile	0.86	0.98	1.14	1.22	1.22	1.21	1.22	1.08	0.89	0.67	0.78	0.94	1.07	1.06	1.07
Leu	1.66	1.82	2.04	2.16	2.16	2.15	2.16	1.97	1.69	1.36	1.48	1.70	1.85	1.84	1.86
Tyr	0.71	0.78	0.89	0.95	0.96	0.96	0.96	0.83	0.68	0.50	0.58	0.67	0.75	0.74	0.78
Phe	1.06	1.19	1.36	1.46	1.47	1.46	1.47	1.30	1.08	0.81	0.94	1.12	1.27	1.26	1.29
His	0.56	0.63	0.71	0.76	0.76	0.75	0.76	0.67	0.57	0.44	0.51	0.61	0.69	0.68	0.69
Lys	1.21	1.38	1.61	1.72	1.72	1.69	1.72	1.50	1.25	0.92	1.09	1.29	1.48	1.47	1.48
Arg	1.50	1.70	1.97	2.11	2.12	2.11	2.13	1.85	1.51	1.09	1.31	1.60	1.86	1.88	1.90
Cys	0.36	0.39	0.43	0.45	0.45	0.44	0.45	0.41	0.35	0.29	0.31	0.36	0.38	0.38	0.38
Met	0.50	0.51	0.53	0.50	0.49	0.47	0.46	0.45	0.42	0.44	0.46	0.51	0.49	0.48	0.47
SAA[2]	0.86	0.89	0.96	0.95	0.93	0.91	0.90	0.86	0.78	0.73	0.77	0.86	0.87	0.86	0.85

Table 7: *Amino acid composition for diets[1] D1, D4, and D5.*

[1]Diet D1 (control), contained synthetic methionine (2kg/2.2 kg). Both D4 and D5 contained 20% organic sunflower seed meal + 20% organic cowpeas that partially replaced corn and soybean meal. D4 contained raw cowpeas and D5 contained heated cowpeas; diets contained no synthetic methionine.

[2] SAA (sulfur amino acids, Cys+Met).

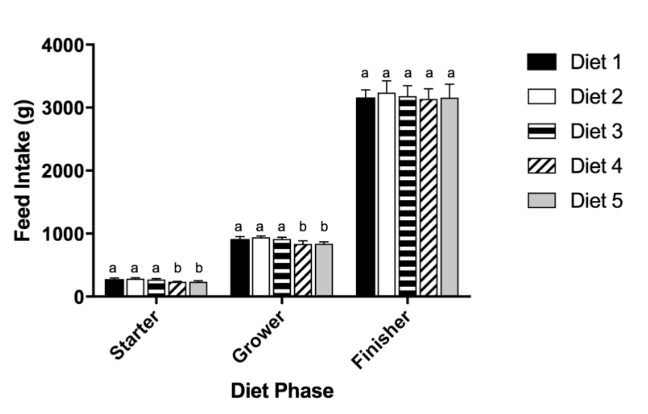

Figure 1: *Feed intake by diet1phase.*

[1]Diet D1 (control), basal diet of organic corn and soybean meal, replaced in D2 with 20% organic sunflower seed meal and in D3 with 20% organic cowpeas. D1, D2, and D3 contained synthetic methionine (2g/2.2 kg). Both D4 and D5 contained 20%organic sunflower seed meal + 20% organic cowpeas that partially replaced corn and soybean meal. D4 contained raw cowpeas and D5 contained heated cowpeas. D4 and D5 contained no synthetic methionine. Different superscripts, a/b, denote significance at P < 0.5.

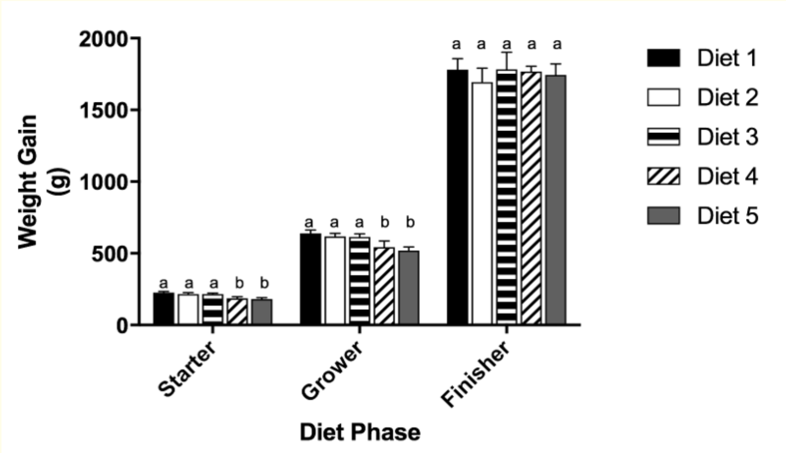

Figure 2: *Weight gain over each diet1phase for all diets.*

[1]Diet D1 (control), basal diet of organic corn and soybean meal, replaced in D2 with 20% organic sunflower seed meal and in D3 with 20% organic cowpeas. D1, D2, and D3 contained synthetic methionine (2g/2.2 kg). Both D4 and D5 contained 20% organic sunflower seed meal + 20% organic cowpeas that partially replaced corn and soybean meal. D4 contained raw cowpeas and D5 contained heated cowpeas. D4 and D5 contained no synthetic methionine.
Different superscripts, a/b, denote significance at P < 0.5.

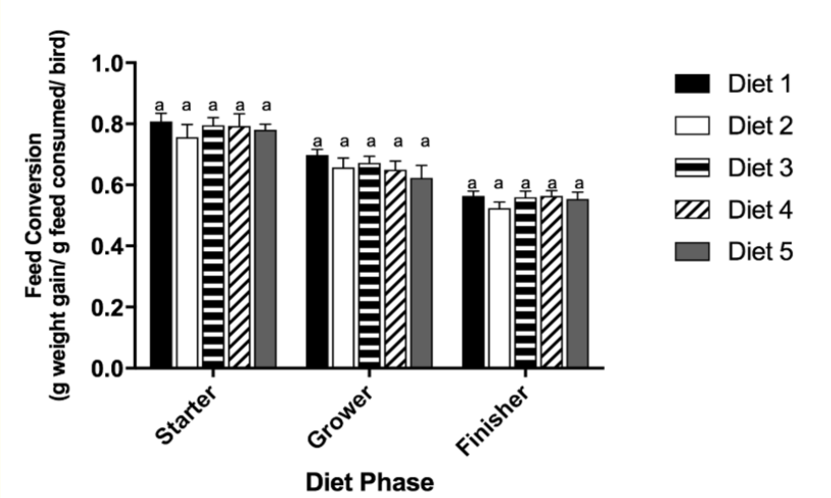

Figure 3: *Feed conversion in each diet1 phase for all diets.*

[1]Diet 1 (control), basal diet of organic corn and soybean meal, replaced in D2 with 20% organic sunflower seed meal and in D3 with 20% organic cowpeas. D1, D2, and D3 contained synthetic methionine (2g/2.2 kg). Both D4 and D5 contained 20% organic sunflower seed meal + 20% organic cowpeas that partially replaced corn and soybean meal. D4 contained raw cowpeas and D5 contained heated cowpeas. D4 and D5 contained no synthetic methionine.
Different superscripts, a/b, denote significance at P < 0.5.

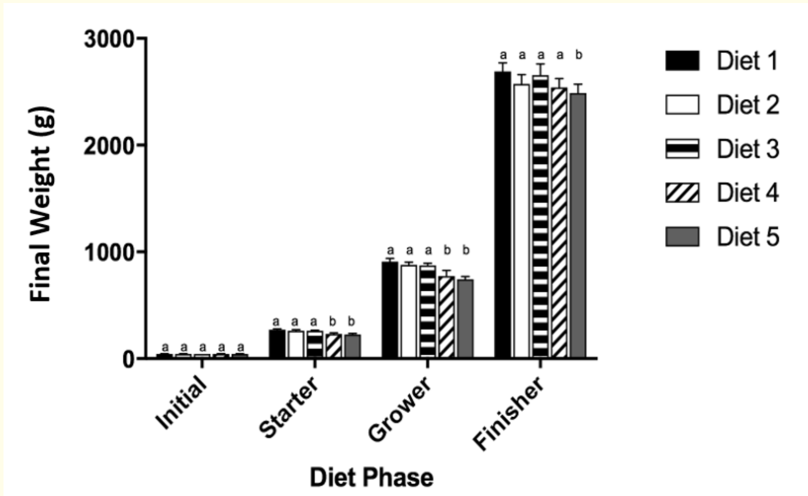

Figure 4: *Final weight of broilers for each diet1 phase for all diets.*

[1]Diet D1 (control), basal diet of organic corn and soybean meal, replaced in D2 with 20% organic sunflower seed meal and in D3 with 20% organic cowpeas. D1, D2, and D3 contained synthetic methionine (2g/2.2 kg). Both D4 and D5 contained 20% organic sunflower seed meal + 20% organic cowpeas that partially replaced corn and soybean meal. D4 contained raw cowpeas and D5 contained heated cowpeas. Organic black-eye peas in D5 were roasted.

Different superscripts, a/b, denote significance at P < 0.5.

Though there were no amino acid imbalances, there were high levels of amino acids in our diets due to excess protein content (Table 7). When compared to other diets, D4 and D5 trended upward for total nitrogen and protein. Protein in D5 was 130%, 136%, and 137% higher than that of D1 in starter, grower, and finisher phases, respectively. Observations also indicated that D2, D4, and D5 had lower total digestible nitrogen (%TDN). Results have shown that high-protein diets improved FCR and produced lean carcasses [33,34]. As the protein content of D4 and D5 well exceeded 28% in order to meet the methionine requirement, their carcasses may have had decreased fat content.

As noted above, legumes, such as cowpeas, also contain anti-nutritional factors such as inhibitors, complex carbohydrates, and acids [18,24]. Abdon *et al.* (2013) recommended roasting cowpeas in an electric oven at 100º C for 15 minutes before adding them to diets in order to produce a final broiler weight significantly similar to that of the control [35]. After roasting cowpeas, Anjos *et al.* (2016) reported no reduction of amino acid levels and a decrease in trypsin inhibitors [20]. Results of our study for D4 (raw CP) and D5 (heated CP) did not fully support these finding.

Issues for use of all vegetable diets

As noted above and by Jacobs (2013), traditional or organic diets using only vegetables as sources of protein may be difficult to produce due to excess protein and amino acids [6,36]. Jacobs (2013) reported that excess plant protein could increase protein nitrogen, excreted as uric acid, ultimately becoming water and ammonia [36]. Moreover, she noted that excess water in fecal matter increased pathogens and breast blisters. As well, excess ammonia may cause respiratory problems and lead to susceptibility for footpad damage and other diseases

[36]. In our work, observations revealed that birds fed D2, D4, and D5 needed more changes of litter (pine shavings) as their manure contained a higher concentration of water. Possibly, this finding was associated not only with effects of indigestible lignocellulosic compounds but also excess uric acid (water and ammonia) caused by the high concentration of nitrogen in the diet [37].

Ultimately, greater nitrogen (NH_3) and hydrogen sulfide from S-containing amino acids, could cause health issues for birds and workers [37,38]. Pre-digestion methods such as the addition of probiotics or post digestion ones (type of litter, housing type) could significantly reduce ammonia and other noxious gases in layer and broiler houses [37,38]. More research to assess the capacity of probiotics and post-digestion methods to reduce (NH_3) in manure of broilers fed diets as provided in the present study is needed.

Use of herbs as sources of methionine

To supply methionine, Hayat *et al.* (2014) fed a synergistic blend of herbs, including *Andrographis paniculata* (green chiretta), *Ocimum sanctum* (holy basil or tulsi), and *Azadirachta indica* (neem) [39]. These herbs are said to mimic methionine activity in the body of poultry [39,40]. The researchers found no significant difference ($P > 0.05$) in feed consumption, weight gain, and FCR when compared to a basal diet with synthetic methionine. More work on use of these and other herbs should be conducted.

Applications

SFSM-CP broilers not receiving synthetic methionine had significantly lower final weights compared to those fed the control with added methionine. If reduction in body weight is due to less fat content, use of the diet may be of value to consumers. Thus, determination of broiler carcass yield, carcass fat, oxidation of fat in thigh meat, α-tocopherol (antioxidant), and the fatty acid profile in all diets should be compared. Likewise, increased ammonia production should be further investigated. More work on use of various herbs that mimic the effect of methionine should be conducted as well.

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