Effect of feeding 3 zero-tannin faba bean cultivars at 3 increasing inclusion levels on growth performance, carcass traits, and yield of saleable cuts of broiler chickens

Femke C. Kopmels,* Miranda N. Smit,[†] Misaki Cho,[‡] Liangfei He,[‡] and Eduardo Beltranena [†,‡,1]

*Department of Animal Sciences, Wageningen University, 6708 WD, Wageningen, the Netherlands; [†]Livestock and Crops Research Division, Alberta Agriculture and Forestry, Edmonton, Alberta, Canada T6H 5T6; and [‡]Department of Agricultural, Food & Nutritional Science, University of Alberta, Edmonton, Alberta, Canada T6G 2P5

ABSTRACT A trial was conducted to evaluate how rapidly one could introduce faba bean in broiler diets and to what maximum level one could feed 3 zero-tannin faba bean cultivars to broiler chickens based on growth performance, carcass traits, and yield of carcass cuts. A total of 662 male broiler chickens (Ross 708) were fed one of 10 dietary treatments over 3 growth phases (starter [**Str**], day 0–12; grower [**Gwr**], day 13–25; and finisher [**Fnr**], day 26–41). Treatment diets included 3 different zero-tannin faba bean cultivars (Snowbird, Snowdrop, and Tabasco), each fed at 3 different inclusions: low inclusion level of 5% in Str, 10% in Gwr, and 20% in Fnr; medium inclusion level of 10% in Str, 20% in Gwr, and 30% in Fnr; and high inclusion level of 15% in Str, 30% in Gwr, and 40% in Fnr. Wheat grain–soybean meal (**SBM**) diets were fed as control. Faba bean cultivars replaced SBM and wheat grain in phase diets. Neither cultivar nor inclusion level affected overall trial or growth phase BW, ADFI, ADG, G:F, slaughter weight (**WT**), chilled carcass WT, and proportion of saleable cuts. Carcass dressing was 0.6% units lower for high vs. medium or low faba bean inclusion level ($P < 0.05$). There was no effect on overall trial or growth phase ADFI and there were only slight reductions ($P < 0.05$) in BW, ADG, G:F, slaughter WT, chilled carcass WT, dressing percentage, and percentage of drumstick yield in broilers fed the treatment diets including faba bean compared with those fed the wheat–SBM control diet. The control diet's advantage was largely attributed to dehulling and the greater extent of processing to produce SBM vs. feeding raw, merely rolled, faba bean. In conclusion, broiler producers can feed any of the 3 zero-tannin faba bean cultivars evaluated as the most aggressive of the 3 inclusion levels tested (15, 30, 40% for the starter, grower, finisher phase) to maximize faba bean inclusion in broiler diets.

Key words: broiler chicken, carcass cut, dietary inclusion, growth performance, zero-tannin faba bean cultivar

2020 Poultry Science 99:4958–4968
https://doi.org/10.1016/j.psj.2020.06.034

INTRODUCTION

Feed represents approximately 70% of the cost of broiler chicken meat production for human consumption (Alltech, 2018). Both starch as a source of energy, and protein as a source of amino acids (**AA**), are the 2 most costly components of broiler feed. Faba bean (*Vicia faba L.*) is a high-yield pulse (low-fat legume) crop that shows potential as the substitute for conventional feedstuffs in broiler feed. Faba bean grain is rich in both starch (33%) and crude protein (**CP**; 28%; Crépon et al., 2010) and grows well in temperate climate zones (north of 50° parallel) where neither corn nor soybean meal (**SBM**) cultivation is optimal (Henriquez et al., 2018). Benefits of faba bean as the crop are numerous, which includes greater grain yield than field pea, a high protein content realized through symbiotic nitrogen fixation, breaking crop disease and pest cycles owing to crop rotation with cereals and oilseeds, diversification of soil microbial ecosystems, and the ability to reduce greenhouse gas emission because of reduced crop inputs (Strydhorst et al., 2008; Köpke and Nemecek, 2010). Besides, slow digestible starch found in faba bean (Hejdysz et al., 2016) can contribute to the improvement of gut health and function in poultry and thereby possibly aid in reducing the need of in-feed antibiotics for therapeutic use (Regassa and Nyachoti, 2018). Surplus food- and

Received January 2, 2020.

Accepted June 11, 2020.

[1]Corresponding author: eduardo.beltranena@ualberta.ca

feed-quality faba bean tonnage is available regionally. Depending on the price, locally grown faba bean represents an opportunity to producers in those regions to reduce feed cost by displacing higher priced ingredients such as imported SBM. The European Commission in 2013 created a Focus Group to enhance the range of protein crops, mainly legumes, to improve the sustainability of European agricultural systems and reduce importation of SBM (Schreuder and Visser, 2014). In general, there is little information on feeding pulses to poultry in comparison with other traditional feedstuffs (e.g., corn, wheat, SBM, fish meal).

Feeding faba bean to poultry also has its downsides: Faba bean contains antinutritional substances (**ANS**) in the form of tannins, trypsin inhibitors, lectins, vicine, convicine, and saponins (Jezierny et al., 2010). The presence of ANS in poultry diets can reduce feed intake and consequently growth (Iji et al., 2004) or egg production and affect the absorption of other nutrients (Crépon et al., 2010). However, lectin and trypsin inhibitor (Valdebouze et al., 1980; Jezierny et al., 2010) as well as saponin levels (Makkar et al., 1997) are substantially lower in faba bean than in SBM. Tannin levels, on the other hand, are considerably greater than in SBM (El-Shemy et al., 2000; Jezierny et al., 2010).

Ingested quantity appears to regulate the effect of tannins (Flores et al., 1994). To mitigate the negative effects of tannins on feed intake and nutrient digestibility, white-flowered, low-tannin (so-called zero-tannin) cultivars of faba bean have been developed (Duc, 1997; Crépon et al., 2010). Zero-tannin faba bean cultivars showed greater apparent ileal digestibility of AA than tannin-containing cultivars and may therefore be a better source of both starch and protein for broiler chickens (Woyengo and Nyachoti, 2012).

Limited information exists on how rapidly or aggressively one can introduce faba bean in broiler diets, what maximum inclusion levels broilers can tolerate according to age, and effects of feeding different zero-tannin faba bean cultivars especially on the yield of carcass meat components. Therefore, the objective of this study was to evaluate the effect of feeding 3 zero-tannin faba bean cultivars at different introduction rates or inclusion levels on growth performance, carcass traits, and yield of saleable cuts. The hypothesis of this study was that broiler chickens fed 3 zero-tannin faba bean cultivars at different introduction rates (increasing inclusion levels) would perform, dress, and yield saleable cuts not different from broilers fed control diets without faba bean.

MATERIALS AND METHODS

Animal use was approved and study procedures were reviewed by the University of Alberta Animal Care and Use Committee for Livestock. Study conduct followed principles established by the Canadian Council on Animal Care (CCAC, 2009). The study was carried out at the Poultry Research and Technology Centre located at the University of Alberta, South Campus (Edmonton, Alberta, Canada).

Animals and Housing

In total, 662 male Ross 708 broiler chickens (Lilydale Hatchery, Spruce Grove, Alberta, Canada) originating from the same flock and hatched on the same day were used in the experiment. Chicks were individually weighed and randomly distributed among 64 cages, with 10 to 11 chicks per cage (initial BW 41.0 ± 3.2 g). Two Specht cage batteries (Specht-Ten Elsen GmbH, Sonsbeck, Germany) were used. Each battery provided 32 cages arranged in 4 tiers, with 2 sides and 4 cages per side. Cages (1.2 m [length] × 0.53 m [width] × 0.43 m [height]) were equipped with metal wire mesh (0.02 × 0.02 m) flooring. Initially, flat plastic mesh (0.01 × 0.01 m) mats covering the entire floor area of each cage were laid on top of the metal flooring to prevent chicks' feet from going through but were subsequently removed on day 7. Broilers had continuous access to water from adjustable height bars that provided 4 nipple drinkers per pen. Cages were also equipped with feed troughs located at the front running the entire length of the cage. From day 0 to 4, parchment paper was placed on the cage floor with test feed sprinkled on top next to the cage feed trough to encourage consumption. During the trial, feed in the troughs was pushed down by hand 2 to 3 times per day as birds aged and consumed more feed, ensuring birds had continuous access to feed at all times. On day 25, up to 2 birds (less if mortality had occurred) with the lowest BW per cage were removed to reduce stocking density to 8 birds per cage. The temperature of the room was reduced as birds aged as per the Ross 708 Production Manual (Aviagen, 2018) and adjusted for low relative humidity in the air. The lighting schedule in the windowless barn conformed to Code of Practice Requirements of National Farm Animal Care Council (NFACC, 2016) and recommendations in the Ross 708 Production Manual (Aviagen, 2018). Broilers were therefore provided 30 to 40 lux, with 23 h of light and 1 h of darkness from day 0 to 2, 22 h of light and 2 h of darkness on day 3, and 21 h of light and 3 h of darkness on day 4; and a minimum 10 to 15 lux, with 20 h of light and 4 h of darkness from day 5 to 41. Automated controllers and timers specific to the test room adjusted temperature, ventilation, and lighting as programmed.

Experimental Design and Diets

Sixty of the 64 cages were divided into 6 area blocks of 10 cages each by location (i.e., battery, tier, side of the battery). In total, 10 different dietary treatments were fed. Each treatment appeared once in each block for a Randomized Complete Block design, with 6 replicate cages per treatment. Birds in the remaining 4 cages were fed the control diets, resulting in 10 replicate cages for the control group only. Cages in blocks 1 and 2 and 2 of the extra control cages had 11 birds per cage; all other cages had 10 birds per cage. Dietary treatments were fed over 3 growth phases (starter, day 0 to 12; grower, day 13 to 25; and finisher, day 26 to 41) for the entire 41-day growth cycle. Control diets were wheat grain–SBM based, similar to what is commonly fed to broiler chickens in the commercial industry in Western Canada (Tables 1–3). Dietary treatments included 3 different zero-tannin (condensed tannin plus monomeric flavan-3-ols ≤ 0.05 g/kg) faba bean cultivars (Snowbird, Snowdrop, and Tabasco), each fed at 3 different inclusion levels: low inclusion level of 5% in the starter phase, 10% in the grower phase, and 20% in the finisher phase; medium inclusion level of 10% in the starter phase, 20% in the grower phase, and 30% in the finisher phase; and high inclusion level of 15% in the starter phase, 30% in the grower phase, and 40% in the finisher phase (Tables 1–3). Test faba bean cultivars replaced SBM and wheat grain in phase diets. Inclusion levels were selected based on what local broiler producers might feed as conservative, moderate, and audacious schemes to reduce feed cost and comparable high levels reported in the literature (Diaz et al. 2006; Laudadio et al. 2011; Ivarsson and Wall, 2017). Diets were formulated without antimicrobials or coccidiostats to provide 12.6, 12.8, and 13.0 MJ AMEn/kg; 1.0, 0.89, and 0.78 g standardized ileal digestible lysine/MJ AMEn; and 0.53, 0.47, and 0.42% digestible P in the starter, grower, and finisher phases, respectively. For faba bean, proximate and AA content were based on actual laboratory results, whereas standardized ileal digestible AA coefficients were taken from AMINODat 5.0 (Evonik Degussa GmbH, Hanau-Wolfgang, Germany). The energy value of faba bean cultivars was assumed to be 10 MJ AMEn/kg based on Sauvant et al. (2004). Other AA were formulated as ideal ratio to lysine and methionine or exceeded nutrient recommendations, except for arginine (in starter diets only) and isoleucine, in faba bean diets. Snowbird faba bean was sourced from Galloway Seeds (Fort Saskatchewan, Alberta, Canada), Snowdrop faba bean was sourced from Shewchuk Seeds (Blaine Lake, Saskatchewan, Canada), and Tabasco faba bean was sourced from Riddell Seed Co. (Warren, Manitoba, Canada). Table 4 shows the analyzed nutrient content of main feedstuffs fed to broilers in this trial. Whole-grain ingredients (wheat, canola seed, faba bean) were rolled through a tandem twin roller mill (model CHD 8.5 × 12; Iowa Farm Automation Ltd., Stanley, IA). The starter diets were mixed in a 60-kg capacity, stainless steel mixer (model PB35; A&M ProcessEquipment Ltd., Ajax, Ontario, Canada). The grower and finisher diets were mixed in a 300-kg capacity, horizontal paddle mixer (model SPC-2748; Marion Process Solutions, Marion, IA). Chickens were fed the assigned diets in mash form.

Measurements and Calculations

To calculate cage ADFI, the amount of feed added during each phase and orts remaining at the end were weighed back on day 12, 25, and 41. To calculate cage ADG, the birds were individually weighed on day 0, 12, 25, and 41. Gain-to-feed ratio (**G:F**) was calculated by dividing cage ADG by ADFI.

Throughout the trial, broilers found dead, ill, or injured were promptly removed, euthanized, and individually weighed, and the suspect reason for death or removal was written down. On day 41 or 42 (late afternoon), the broilers were crated and transported (500 m) to the site abattoir, where they had no access to feed or water overnight. The broilers were slaughtered early the following morning and processed following commercial conditions (day 42–43 of age). Before slaughter, antemortem weight (**WT**) of individual broilers was measured. Broilers were euthanized by electrically stunning, bled out and then scalded, defeathered, and eviscerated. Carcasses were blast chilled to 4°C (measured in breast) and weighed to calculate the dressing percentage. One half of the carcasses randomly selected from each cage were then broken down into saleable cuts (breast including *Pectoralis* major and minor, thighs, drumsticks, and wings) and weighed to calculate yield relative to chilled carcass WT.

Chemical Analyses

Feedstuffs and diets were ground through a 0.5-mm screen in a centrifugal mill (ZM 200; Retsch GmbH, Haan, Germany). Feedstuffs and diets were analyzed using the Association of Official Analytical Chemists (AOAC, 2016), American Oil Chemists' Society (AOCS, 2017), or Ankom Technology (2017) methods for moisture (AOAC 930.15), CP (AOAC 990.03[M]), AA (AOAC 994.12), starch (enzymatic UV method, Cat. No. 10207748035; R-Biopharm, Darmstadt, Germany), crude fiber (AOCS BA 6a-05), neutral detergent fiber (**NDF**; Ankom method 13[M]), acid detergent fiber (**ADF**; Ankom method 12[M]), crude fat (AOCS Am 5-04), and ash (AOAC 923.03) as well as calcium, phosphorus, sodium, chloride, magnesium, and potassium content (AOAC 985.01 [M], AOAC 968.08 [M], and AOAC 935.13a [M]) at Central Testing Laboratory Ltd. (Winnipeg, Manitoba, Canada). Gross energy for diet and feed ingredient samples was measured in duplicate by bomb calorimetry (model 6050; Parr Instrument Company, Moline, IL) in our laboratory (Alberta Agriculture and Forestry, Edmonton, Canada). Feed ingredient and diet particle size was determined in-house using a Ro-Tap (model RX-29; W.S. Tyler, Ontario, Canada) equipped with 13 sieves and a pan, following the method of American Society of Agricultural and Biological Engineers (2008).

Statistical Analyses

Growth performance, carcass traits, and saleable meat cut data were analyzed using a generalized linear model (GLIMMIX procedure) in SAS 9.4 (SAS Institute, Cary, NC) using a normal distribution and the identity link function (SAS Institute, 2017). Cage was the experimental unit for all variables. Data were analyzed as a 3 × 3 factorial design excluding the control; a contrast statement compared all faba bean treatments with the control diet. Models for the factorial design included the fixed effects of faba bean cultivars (Snowbird, Snowdrop, and Tabasco), faba bean

Table 1. Ingredient composition, particle size, and analyzed nutrient content of starter diets[1] including 3 zero-tannin faba bean grain cultivars (Snowbird, Snowdrop, Tabasco) fed at 3 different levels[2] and control diet.

		Snowbird[3]			Snowdrop[4]			Tabasco[5]		
Ingredient, % as-fed	Control	Low[2]	Medium[2]	High[2]	Low	Medium	High	Low	Medium	High
Wheat, rolled	55.72	52.57	49.41	46.37	52.56	49.42	46.27	52.56	49.41	46.26
Soybean meal	20.70	18.50	16.30	14.00	18.50	16.30	14.10	18.50	16.30	14.10
Snowbird, rolled		5.00	10.00	15.00						
Snowdrop, rolled					5.00	10.00	15.00			
Tabasco, rolled								5.00	10.00	15.00
Canola seed, rolled	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Fish meal	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Limestone	0.70	0.70	0.71	0.72	0.71	0.72	0.73	0.71	0.73	0.73
Monocalcium/dicalcium phosphate	0.60	0.60	0.59	0.57	0.60	0.58	0.57	0.60	0.58	0.58
Broiler premix[6]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Sodium bicarbonate	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Canola oil		0.30	0.60	0.90	0.30	0.60	0.90	0.30	0.60	0.90
L-Lysine HCl	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
DL-Methionine	0.24	0.26	0.29	0.31	0.26	0.29	0.31	0.26	0.29	0.31
L-Threonine	0.18	0.19	0.20	0.21	0.19	0.20	0.21	0.19	0.20	0.21
Choline chloride, 60%	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
L-Valine	0.06	0.08	0.10	0.12	0.08	0.09	0.11	0.08	0.09	0.11
Superzyme Plus[7]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Analyzed nutrients,[8] %										
Crude protein	26.58	26.34	26.02	25.28	25.49	26.17	26.72	25.79	26.57	26.96
Neutral detergent fiber	9.60	9.66	9.05	10.21	9.90	9.76	9.34	9.57	9.64	10.59
Acid detergent fiber	4.10	4.40	3.96	4.62	4.86	4.16	4.25	4.08	4.98	4.30
Crude fiber	3.61	3.63	3.61	3.57	3.69	3.66	3.76	3.86	3.83	4.02
Ether extract	6.92	7.37	7.58	7.89	7.32	7.93	7.69	7.39	7.64	8.14
Ash	6.70	6.60	6.36	6.46	6.12	6.50	6.63	6.51	6.16	6.53
Calcium	1.33	1.30	1.24	1.20	1.17	1.29	1.33	1.22	1.17	1.26
Potassium	0.92	0.93	0.92	0.91	0.94	0.94	0.93	0.94	0.93	0.93
Phosphorus	0.88	0.92	0.86	0.85	0.85	0.89	0.91	0.88	0.88	0.91
Chloride	0.51	0.56	0.50	0.54	0.46	0.54	0.53	0.50	0.50	0.59
Sodium	0.31	0.35	0.30	0.31	0.28	0.33	0.33	0.30	0.30	0.36
Magnesium	0.18	0.18	0.18	0.17	0.19	0.19	0.18	0.19	0.18	0.18
Indispensable amino acids										
Arginine	1.58	1.70	1.62	1.62	1.58	1.66	1.66	1.66	1.82	1.76
Histidine	0.67	0.42	0.68	0.62	0.70	0.69	0.71	0.70	0.76	0.67
Isoleucine	1.09	1.23	1.14	0.99	1.14	1.13	1.13	1.14	1.22	1.14
Leucine	1.83	1.81	1.84	1.80	1.83	1.86	1.86	1.85	1.98	1.88
Lysine	1.43	1.58	1.49	1.53	1.42	1.56	1.44	1.49	1.58	1.59
Methionine	0.77	0.79	0.77	0.72	0.75	0.84	0.78	0.71	0.73	0.83
Phenylalanine	1.25	1.25	1.23	1.13	1.24	1.21	1.28	1.23	1.32	1.19
Threonine	0.91	0.97	0.85	0.98	0.67	0.82	0.87	0.80	0.83	0.93
Tryptophan	0.35	0.33	0.41	0.33	0.32	0.33	0.33	0.39	0.34	0.34
Valine	1.35	1.58	1.44	1.32	1.41	1.43	1.44	1.43	1.56	1.50
Dispensable amino acids										
Alanine	1.05	1.52	1.07	1.08	1.08	1.09	1.07	1.07	1.15	1.10
Aspartic acid	2.07	2.48	2.12	2.19	2.13	2.18	2.11	2.12	2.23	2.23
Cysteine	0.69	0.62	0.62	0.56	0.61	0.64	0.61	0.61	0.63	0.61
Glutamic acid	4.85	5.24	4.78	4.80	4.89	4.81	4.74	4.86	5.10	4.86
Glycine	1.34	1.36	1.36	1.25	1.36	1.34	1.42	1.35	1.49	1.34
Proline	1.82	1.69	1.75	1.63	1.83	1.73	1.83	1.76	1.89	1.70
Serine	0.92	0.70	0.69	1.12	0.52	0.78	0.84	0.69	0.64	0.83
Tyrosine	0.88	0.85	0.85	0.84	0.85	0.85	0.92	0.85	0.92	0.86
Particle size,[9] µm	675	697	727	708	727	761	821	750	778	788
Particle size standard deviation, µm	2.32	2.30	2.19	2.22	2.21	2.22	2.12	2.28	2.17	2.17
Gross energy,[9] MJ/kg	17.55	17.53	17.57	17.65	17.60	17.62	17.56	17.64	17.62	17.69

[1]Starter diets fed from day 0–12.
[2]Faba bean grain inclusion: low, 5%; medium, 10%; high, 15%.
[3]Galloway Seeds (Fort Saskatchewan, Alberta, Canada).
[4]Shewchuk Seeds (Blaine Lake, Saskatchewan, Canada).
[5]Riddell Seed Co. (Warren, MB, Canada).
[6]Provided per kg of diet: vitamin A, 10,000 IU; vitamin D3, 4,000 IU; vitamin E, 50 IU; menadione, 4 mg; biotin, 0.2 mg; folic acid, 2 mg; niacin, 65 mg; pantothenic acid, 15 mg; pyridoxine, 5 mg; riboflavin, 10 mg; thiamine, 4 mg; vitamin B12, 0.02 mg; copper, 20 mg; iodine, 1.65 mg; iron, 80 mg; manganese, 120 mg; selenium, 0.3 mg; and zinc, 100 mg.
[7]Provided per kg of diet, units: amylase, 12,000; cellulase, 500; glucanase, 150; invertase, 700; mannase, 60; phytase, 1,000; protease, 1,200; and xylanase, 1,200.
[8]Central Testing Laboratory Ltd. (Winnipeg, Manitoba, Canada). Standardized to 11% moisture.
[9]Alberta Agriculture and Forestry (Edmonton, Alberta, Canada).

Table 2. Ingredient composition, particle size, and analyzed nutrient content of grower diets[1] including 3 zero-tannin faba bean grain cultivars (Snowbird, Snowdrop, Tabasco) fed at 3 different levels[2] and control diet.

		Snowbird[3]			Snowdrop[4]			Tabasco[5]		
Ingredients, % as-fed	Control	Low[2]	Medium[2]	High[2]	Low	Medium	High	Low	Medium	High
Wheat, rolled	54.22	48.04	41.73	35.75	47.92	41.62	35.31	47.90	41.57	35.44
Soybean meal	22.50	18.00	13.60	9.00	18.10	13.70	9.30	18.10	13.70	9.20
Snowbird, rolled		10.00	20.00	30.00						
Snowdrop, rolled					10.00	20.00	30.00			
Tabasco, rolled								10.00	20.00	30.00
Canola seed, rolled	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Fish meal	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Canola oil	0.90	1.50	2.10	2.60	1.50	2.10	2.70	1.50	2.10	2.60
Limestone	0.70	0.71	0.74	0.74	0.73	0.75	0.79	0.74	0.76	0.78
Mono-/di-calcium phosphate	0.70	0.67	0.64	0.61	0.67	0.64	0.60	0.68	0.68	0.68
Broiler premix[6]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Sodium bicarbonate	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
L-Lysine HCl	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.20	0.25	0.29	0.34	0.25	0.29	0.34	0.25	0.29	0.34
L-Threonine	0.13	0.15	0.18	0.20	0.15	0.18	0.20	0.15	0.18	0.20
Choline chloride 60%	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
L-Valine		0.03	0.07	0.11	0.03	0.07	0.11	0.03	0.07	0.11
Superzyme Plus[7]	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Analyzed nutrients,[8] %										
Crude protein	23.30	24.43	24.00	23.29	24.22	24.29	23.00	24.23	23.93	24.05
Neutral detergent fiber	10.09	10.81	11.13	9.59	11.09	9.73	10.10	10.62	10.02	10.72
Acid detergent fiber	4.33	5.15	4.79	4.75	5.73	5.36	5.11	5.00	5.18	4.85
Crude fiber	3.96	4.67	4.07	4.17	4.02	3.84	4.70	4.49	4.16	4.47
Ether extract	8.81	9.80	10.37	10.68	11.44	9.77	10.28	9.14	9.70	10.58
Ash	5.80	5.53	5.46	5.38	5.78	5.65	5.28	5.62	5.40	5.70
Calcium	0.99	0.95	0.95	0.99	1.01	1.01	0.91	0.94	0.88	0.99
Potassium	0.96	0.99	0.98	0.95	0.97	0.95	0.85	0.88	0.87	0.87
Phosphorus	0.77	0.77	0.77	0.77	0.80	0.76	0.68	0.72	0.71	0.76
Chloride	0.48	0.43	0.45	0.44	0.47	0.46	0.44	0.46	0.44	0.52
Sodium	0.29	0.26	0.28	0.27	0.28	0.28	0.25	0.26	0.25	0.28
Magnesium	0.20	0.20	0.19	0.18	0.20	0.18	0.16	0.17	0.17	0.17
Indispensable amino acids										
Arginine	1.50	1.54	1.52	1.57	1.59	1.58	1.66	1.63	1.67	1.76
Histidine	0.67	0.66	0.66	0.63	0.67	0.66	0.66	0.64	0.65	0.65
Isoleucine	1.09	1.09	0.90	1.02	0.99	0.93	0.82	0.96	0.85	0.91
Leucine	1.77	1.78	1.68	1.70	1.76	1.69	1.68	1.74	1.70	1.72
Lysine	1.33	1.42	1.29	1.43	1.36	1.33	1.35	1.38	1.35	1.38
Methionine	0.62	0.61	0.71	0.77	0.69	0.61	0.69	0.69	0.64	0.79
Phenylalanine	1.23	1.17	1.15	1.08	1.20	1.12	1.11	1.14	1.12	1.07
Threonine	0.78	0.79	0.89	0.85	0.93	0.88	0.93	0.93	0.93	0.98
Tryptophan	0.34	0.35	0.31	0.36	0.34	0.33	0.28	0.33	0.30	0.28
Valine	1.26	1.32	1.14	1.32	1.20	1.17	1.10	1.17	1.10	1.21
Dispensable amino acids										
Alanine	0.97	1.00	0.93	0.95	0.98	0.93	0.96	0.99	0.97	0.99
Aspartic acid	2.01	2.14	1.99	2.05	2.05	1.98	2.07	2.13	2.09	2.16
Cysteine	0.65	0.61	0.61	0.61	0.66	0.56	0.59	0.61	0.58	0.61
Glutamic acid	4.89	4.85	4.34	4.40	4.64	4.30	4.32	4.84	4.58	4.48
Glycine	1.23	1.18	1.18	1.13	1.22	1.15	1.21	1.16	1.17	1.15
Proline	1.79	1.66	1.63	1.48	1.70	1.57	1.59	1.65	1.66	1.50
Serine	0.79	0.76	1.04	0.84	1.05	1.02	1.13	1.09	1.13	1.09
Tyrosine	0.85	0.83	0.87	0.79	0.90	0.86	0.90	0.84	0.85	0.84
Particle size,[9] µm	821	907	968	1,026	931	798	939	831	896	927
Particle size standard deviation, µm	2.04	1.99	1.94	1.96	1.94	2.17	1.94	1.97	1.92	1.91
Gross energy,[9] MJ/kg	18.04	18.34	18.35	18.38	18.42	18.36	18.47	17.98	18.28	18.17

[1]Grower diets fed from day 13–25.

[2]Faba bean grain inclusion: low, 10%; medium, 20%; high, 30%.

[3]Galloway Seeds (Fort Saskatchewan, Alberta, Canada).

[4]Shewchuk Seeds (Blaine Lake, Saskatchewan, Canada).

[5]Riddell Seed Co. (Warren, MB, Canada).

[6]Provided per kg of diet: vitamin A, 10,000 IU; vitamin D3, 4,000 IU; vitamin E, 50 IU; menadione, 4 mg; biotin, 0.2 mg; folic acid, 2 mg; niacin, 65 mg; pantothenic acid, 15 mg; pyridoxine, 5 mg; riboflavin, 10 mg; thiamine, 4 mg; vitamin B12, 0.02 mg; copper, 20 mg; iodine, 1.65 mg; iron, 80 mg; manganese, 120 mg; selenium, 0.3 mg, and zinc, 100 mg.

[7]Provided per kg of diet, units: amylase, 6,000; cellulose, 250; glucanase, 75; invertase, 350; mannase, 30; phytase, 500; protease, 600; and xylanase, 600.

[8]Central Testing Laboratory Ltd. (Winnipeg, Manitoba, Canada). Standardized to 11% moisture.

[9]Alberta Agriculture and Forestry (Edmonton, Alberta, Canada).

Table 3. Ingredient composition, particle size, and analyzed nutrient content of finisher diets[1] including 3 zero-tannin faba bean grain cultivars (Snowbird, Snowdrop, Tabasco) fed at 3 different levels[2] and control diet.

		Snowbird[3]			Snowdrop[4]			Tabasco[5]		
Ingredients, % as fed	Control	Low[2]	Medium[2]	High[2]	Low	Medium	High	Low	Medium	High
Wheat, rolled	58.45	46.13	40.05	33.91	46.03	39.65	33.36	46.01	39.59	33.27
Soybean meal	22.80	13.80	9.30	4.80	13.90	9.60	5.20	13.90	9.60	5.20
Snowbird, rolled		20.00	30.00	40.00						
Snowdrop, rolled					20.00	30.00	40.00			
Tabasco, rolled								20.00	30.00	40.00
Canola seed, rolled	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Monocalcium/dicalcium phosphate	1.00	0.95	0.90	0.86	0.94	0.90	0.86	0.96	0.95	0.95
Limestone	0.87	0.90	0.92	0.93	0.92	0.94	0.97	0.92	0.95	0.97
Broiler premix[6]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Canola oil	0.20	1.40	1.90	2.45	1.40	2.00	2.60	1.40	2.00	2.60
Sodium bicarbonate	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
L-Lysine HCl	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
DL-Methionine	0.11	0.20	0.25	0.29	0.20	0.25	0.30	0.20	0.25	0.30
L-Threonine	0.07	0.11	0.13	0.16	0.11	0.13	0.15	0.11	0.13	0.15
Superzyme Plus[7]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Choline chloride 60%	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
L-Valine		0.01	0.05	0.10		0.03	0.06		0.03	0.06
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Analyzed nutrients,[8] %										
Crude protein	22.10	20.98	21.19	20.24	21.51	21.75	20.50	21.60	21.64	20.59
Neutral detergent fiber	9.93	9.84	10.61	10.35	9.68	10.08	10.40	9.59	9.53	11.20
Acid detergent fiber	4.83	4.60	5.48	7.01	5.48	6.19	7.73	5.10	5.34	7.19
Crude fiber	4.73	4.49	4.41	5.56	4.25	4.52	5.30	4.11	3.92	5.89
Ether extract	10.72	9.09	9.93	10.48	9.43	9.98	10.25	8.99	9.55	10.26
Ash	5.35	4.98	5.06	5.12	5.38	4.70	4.72	5.18	4.84	4.75
Calcium	0.88	0.82	0.82	0.89	0.95	0.71	0.78	0.84	0.84	0.83
Potassium	0.91	0.86	0.85	0.83	0.85	0.83	0.80	0.85	0.86	0.85
Phosphorus	0.69	0.62	0.61	0.60	0.64	0.57	0.58	0.66	0.69	0.64
Chloride	0.45	0.44	0.44	0.47	0.49	0.37	0.41	0.42	0.40	0.41
Sodium	0.24	0.22	0.23	0.26	0.27	0.20	0.21	0.23	0.22	0.23
Magnesium	0.19	0.17	0.16	0.16	0.18	0.16	0.16	0.17	0.17	0.17
Indispensable amino acids										
Arginine	1.35	1.40	1.36	1.59	1.37	1.39	1.43	1.52	1.64	1.58
Histidine	0.63	0.59	0.59	0.67	0.61	0.56	0.59	0.61	0.62	0.59
Isoleucine	0.91	0.84	0.77	1.00	0.89	0.66	0.83	0.80	0.79	0.77
Leucine	1.62	1.54	1.48	1.67	1.51	1.43	1.45	1.58	1.58	1.47
Lysine	1.19	1.26	1.21	1.38	1.15	1.17	1.16	1.21	1.23	1.14
Methionine	0.47	0.52	0.62	0.61	0.62	0.57	0.57	0.56	0.58	0.59
Phenylalanine	1.12	0.98	0.95	1.08	1.03	0.93	0.94	1.04	1.02	0.94
Threonine	0.78	0.85	0.79	0.87	0.71	0.81	0.77	0.79	0.80	0.77
Tryptophan	0.31	0.28	0.30	0.24	0.28	0.26	0.26	0.30	0.28	0.26
Valine	1.06	1.01	0.96	1.34	1.04	1.17	1.04	0.95	0.96	0.96
Dispensable amino acids										
Alanine	0.86	0.84	0.81	0.89	0.80	0.82	0.77	0.85	0.85	0.77
Aspartic acid	1.90	1.95	1.85	2.05	1.80	1.92	1.76	1.86	1.94	1.76
Cysteine	0.54	0.59	0.62	0.54	0.57	0.57	0.53	0.60	0.60	0.56
Glutamic acid	4.73	4.73	4.14	4.52	4.17	4.18	3.86	4.48	4.28	3.78
Glycine	1.01	0.93	0.93	1.07	0.98	0.94	0.94	1.00	1.01	0.94
Proline	1.66	1.45	1.39	1.49	1.50	1.42	1.34	1.55	1.50	1.34
Serine	1.00	1.01	0.98	0.92	0.84	1.03	0.85	1.04	1.03	0.92
Tyrosine	0.80	0.72	0.71	0.78	0.74	0.71	0.72	0.77	0.77	0.73
Particle size,[9] μm	911	885	966	1,004	980	975	1,021	918	987	1,098
Particle size standard deviation, μm	1.92	1.96	1.95	1.92	1.86	1.89	1.89	1.92	1.90	1.85
Gross energy,[9] MJ/kg	17.76	17.92	17.95	18.15	18.04	18.19	18.26	18.08	17.94	18.04

[1]Finisher diets fed from day 26–41.
[2]Faba bean grain inclusion: low, 20%; medium, 30%; high, 40%.
[3]Galloway Seeds (Fort Saskatchewan, Alberta, Canada).
[4]Shewchuk Seeds (Blaine Lake, Saskatchewan, Canada).
[5]Riddell Seed Co. (Warren, MB, Canada).
[6]Provided per kg of diet: vitamin A, 10,000 IU; vitamin D3, 4,000 IU; vitamin E, 50 IU; menadione, 4 mg; biotin, 0.2 mg; folic acid, 2 mg; niacin, 65 mg; pantothenic acid, 15 mg; pyridoxine, 5 mg; riboflavin, 10 mg; thiamine, 4 mg; vitamin B12, 0.02 mg; copper, 20 mg; iodine, 1.65 mg; iron, 80 mg; manganese, 120 mg; selenium, 0.3 mg; and zinc, 100 mg.
[7]Provided per kg of diet, units: amylase, 12,000; cellulose, 500; glucanase, 150; invertase, 700; mannase, 60; phytase, 1,000; protease, 1,200; and xylanase, 1,200.
[8]Central Testing Laboratory Ltd. (Winnipeg, Manitoba, Canada). Standardized to 11% moisture.
[9]Alberta Agriculture and Forestry (Edmonton, Alberta, Canada).

Table 4. Analyzed nutrient content (as-fed basis) and particle size of zero-tannin Snowbird, Snowdrop, and Tabasco faba bean grain cultivars, wheat grain, soybean meal (SBM), and canola seed.

Analyzed nutrients, %	Snowbird[1]	Snowdrop[2]	Tabasco[3]	Wheat	SBM	Canola seed
Moisture	12.61	10.86	12.26	12.53	11.46	8.07
Starch	40.39	40.17	37.47	55.64	0.40	0.51
Crude protein	24.85	24.31	27.09	13.91	46.44	21.89
Neutral detergent fiber	9.49	11.48	12.45	9.91	7.51	20.49
Acid detergent fiber	6.75	10.24	10.94	2.17	6.03	18.62
Crude fiber	5.29	8.15	8.70	2.05	3.48	14.09
Ether extract	1.18	1.18	0.96	1.96	1.47	40.37
Ash	2.69	2.46	2.57	1.82	5.39	3.44
Potassium	1.21	1.07	1.16	0.42	2.28	0.71
Phosphorus	0.41	0.39	0.50	0.36	0.67	0.60
Calcium	0.11	0.13	0.09	0.11	0.25	0.41
Magnesium	0.12	0.12	0.13	0.12	0.26	0.31
Chloride	0.07	0.06	0.05	0.06	0.01	0.01
Sodium	0.01	0.01	0.00	0.01	0.01	0.03
Indispensible amino acids						
Arginine	2.01	2.17	2.54	0.66	3.03	1.31
Histidine	0.69	0.74	0.69	0.41	1.12	0.65
Isoleucine	0.98	1.08	1.05	0.55	1.10	0.77
Leucine	1.84	1.89	1.86	0.96	3.23	1.53
Lysine	1.56	1.46	1.46	0.36	2.53	1.20
Methionine	0.25	0.25	0.25	0.29	0.70	0.48
Phenylalanine	1.11	1.18	1.10	0.71	2.22	0.95
Threonine	0.83	0.81	0.76	0.31	1.56	0.86
Tryptophan	0.26	0.27	0.31	0.20	0.68	0.27
Valine	1.12	1.22	1.22	0.67	1.65	1.00
Dispensable amino acids						
Alanine	1.00	1.00	0.98	0.47	1.86	0.92
Aspartic acid	2.73	2.69	2.66	0.71	5.15	1.52
Cysteine	0.50	0.51	0.52	0.57	0.93	0.88
Glutamic acid	4.01	4.02	3.99	3.98	7.95	3.74
Glycine	1.11	1.22	1.13	0.64	1.96	1.19
Proline	1.11	1.22	1.16	1.56	2.45	1.54
Serine	1.20	1.11	1.02	0.41	2.37	0.96
Tyrosine	0.88	0.91	0.87	0.48	1.66	0.76
Particle size,[4] µm	951	1,019	1,052	814	785	1,099
Particle size standard deviation, µm	1.94	2.03	1.87	2.24	1.91	1.62
Gross energy,[4] MJ/kg	16.29	16.63	16.38	16.31	17.56	26.83

[1]Galloway Seeds (Fort Saskatchewan, Alberta, Canada).
[2]Shewchuk Seeds (Blaine Lake, Saskatchewan, Canada).
[3]Riddell Seed Co. (Warren, MB, Canada).
[4]Alberta Agriculture and Forestry (Edmonton, Alberta, Canada).

inclusion levels (low, medium, and high), and interaction. Block was the random term in the model.

Overall growth performance variables (ADFI, ADG, and G:F) were analyzed using closeout data. Live performance data were also analyzed as per growth phase. For carcass data, the sampling unit was individual carcasses. The model for carcass-related data included cage (cultivar, inclusion level) for the 3 × 3 factorial design or cage (treatment) for the contrast analysis as a random effect to take into account that the sampling unit (individual carcasses) was not the same as the experimental unit (cage). To test hypotheses, $P < 0.05$ was considered significant; $P < 0.10$ was considered a trend.

RESULTS AND DISCUSSION

A major reason for not feeding locally grown feed commodities is lack of information on the effect of feeding pulses including faba bean to broiler chickens. Information such as the maximum level to feed by age, how fast to introduce, and effects on carcass traits and proportional yield of saleable cuts is nonexistent. Research published on broilers feeding diets containing faba bean has focused on live bird performance and digestibility (Gous, 2011; Woyengo and Nyachoti, 2012; Ivarsson and Wall, 2017), not on carcass traits, meat yield, or quality attributes. The present trial therefore looked at live growth performance, carcass traits, and yield of saleable cuts. Besides, previous research often fed pelleted diets (Farrell et al., 1999; Nalle et al., 2010). Pelleted diets increase digestibility of both protein and starch, resulting in greater AMEn values (Lacassagne et al., 1988). Ivarsson and Wall (2017) reported greater feed intake feeding pelleted diets containing zero-tannin faba bean than feeding the same in mash form. Broiler producers that mix feed on farm often do not have pellet mills. Our broilers were fed mash diets to replicate how local producers feed their flocks.

Diet Formulation

Different introduction rates or increasing dietary inclusion levels of faba bean were fed to broilers in this experiment instead of just comparing graded inclusion levels that would not change with feeding phase or remain constant throughout the trial (Cho et al., 2019). The reason for this was to challenge the birds and determine to what maximum level and how fast one could introduce faba bean, but also to determine if feeding broilers faba bean at different inclusion rates would result in reduced growth performance. Tolerance to ANS appears to increase as birds age (Farrell et al., 1999). By feeding faba bean at different increasing inclusion levels instead of constant levels that would not increase by phase, broilers were given the opportunity to progressively adapt to high inclusions of faba bean, their effect at the gut level and the challenge that the increasing level of ANS in the diet implied.

An issue feeding faba bean is the lack of reliable nutritional information. Although information on the AME and the variability thereof in faba bean fed to broilers is lacking, it is not completely unknown. Availability of reliable energy values is, however, far more limiting than AA digestibility values, and cultivar effects are unknown. As mentioned earlier, most AA ratios met or exceeded the required ratios to lysine even at high faba bean inclusions (30–40%). However, the required ratios were not always met using the AMINODat 5.0 matrix of digestible AA coefficients. Arginine (only in starter) and branched-chain AA were deficient in formulations. For this reason, L-valine, now commercially available in Canada, was added to faba bean diets. Branched-chain AA are known to be limiting in faba bean, but overall, analyzed contents in diet were not found to be retrospectively lower in the experimental diets (Tables 1–3) than levels recommended in the Ross 708 Production Manual (Aviagen, 2019). Protein content was about 3% points lower than expected.

Particle size was measured for all experimental diets, faba bean cultivars, wheat grain, SBM, and canola seed (Tables 1–4). The recommended particle size should be between 600 and 800 μm. Chickens are known to prefer larger feed particles, and such preference increases with age (Nir et al., 1994). Uniform particle size diets should result in less time spent searching for and selecting preferred particle sizes, which would lead to superior broiler performance. In the present study, particle size was slightly greater than recommended for grower and finisher but not for starter diets (Tables 1–3). However, the standard deviation of the particle size of our diets was lower than the typically observed 2.7 μm, likely owing to rolling. The increase in particle size with the feeding phase in our experiment is explained by increasing faba bean and canola seed inclusions as the trial progressed and broilers grew older.

Growth Performance

Throughout the trial, 36 birds were either found dead or removed and euthanized because illness, leg or wing injury. Because of this low removal rate (lack of replication), no statistical analysis was conducted. Reasons for assumed death or removal seemed not to be related to dietary treatment.

There were no interactions between faba bean cultivar and dietary inclusion level on growth performance or carcass traits. The most important finding in this experiment was that neither faba bean cultivars nor inclusion levels had an effect on overall trial or individual growth phase ADFI, ADG, G:F, or BW (Table 5). Ivarsson and Wall (2017) showed that broiler growth performance was maintained by feeding pelleted diets with 20% zero-tannin faba bean inclusion, but reduced ADFI and BW was observed at an inclusion level of 30%. According to that study, a lower level of available AA because of lower digestibility might explain the decrease in the growth rate at high inclusion levels. In that study, at the 30% inclusion level, the feed conversion ratio was improved, compared with the 20% inclusion level and the control diet. This finding indicated that decreased feed intake was responsible for the lower BW. In the present study, no effects on feed intake were observed, and hence, faba bean cultivars or inclusion levels had no effect on growth performance. The difference between our study and that of Ivarsson and Wall (2017) could be due to phase feeding. Ivarsson and Wall (2017) fed a single-phase diet throughout the trial, whereas our study implemented phase feeding. Our results indicate that zero-tannin cultivars Snowbird, Snowdrop, and Tabasco introduced at the high inclusion level (15, 30, and 40% for the starter, grower, and finisher phase, respectively) can be fed to broilers without affecting growth performance (Table 5).

The controls were heavier at the end of the grower and finisher phases, had greater ADG for the overall trial (66.7 vs. 63.3 g/day) and at the starter and grower phases, and had greater G:F for the overall trial (0.612 vs. 0.581 g/g) and the finisher phase than broilers fed faba bean ($P < 0.05$; Table 5). No effects on ADFI were observed (Table 5), indicating that the broilers did not prefer control over faba bean–containing phase diets. In our study, broilers were fed raw faba bean merely rolled that was not processed to the same extent as SBM. Production of SBM involves many processing steps including flaking, dehulling, heating, pressing, hexane washing, and desolventizing (Wright, 1981). Seed heating steps reduce trypsin inhibitor levels and increase AA digestibility of SBM (Wright, 1981; Rada et al., 2017). Hence, it was not surprising to us to observe somewhat reduced growth performance in broilers fed raw, rolled-only faba bean compared with those fed highly processed SBM. We showed similar small reductions in growth performance in a recent study that fed broilers with whole or dehulled zero- or high-tannin faba bean cultivars compared with a SBM–wheat control diet (Cho et al., 2019). Processing of faba bean might nullify the reductions observed in growth performance. Indeed, when Laudadio et al. (2011) fed broilers processed, dehulled, and micronized zero-tannin faba bean as replacement for SBM at 31% inclusion level, growth performance was not affected up to 49 days of age.

Carcass Traits

Faba bean cultivar or inclusion level had no effect on antemortem WT or chilled carcass WT, but the high

Table 5. Effect of feeding 3 zero-tannin faba bean grain cultivars at 3 dietary inclusion levels on live body weight (BW), average daily feed intake (ADFI), weight gain (ADG), and feed efficiency (ADG/ADFI; G:F) of broiler chickens to 41 days of age[1].

		Cultivar			Inclusion				*P*-value		
Variable	Control	Snowbird	Snowdrop	Tabasco	Low	Medium	High	SEM[2]	Cultivar	Inclusion	Contrast[3]
BW day 0, g/bird	40.8	41.1[a,b]	41.5[a]	40.4[b]	41.1	40.9	41.1	0.3	0.0244	0.8039	0.5883
BW day 12, g/bird	398.6	386.2	383.6	381.0	382.2	389.3	379.3	3.8	0.6037	0.1495	0.0273
BW day 25, g/bird	1,369.2	1,276.5	1,283.3	1,278.6	1,277.8	1,289.4	1,271.2	29.0	0.9488	0.6990	0.0035
BW day 41, g/bird	3,011.1	2,875.7	2,881.8	2,868.7	2,883.6	2,899.9	2,842.8	33.0	0.9617	0.4587	0.0359
ADFI day 0–12,[4] g/bird	37.3	37.3	37.5	38.6	37.8	37.9	37.7	1.1	0.3935	0.9702	0.7284
ADFI day 13–25,[5] g/bird	103.9	98.9	98.6	98.8	99.8	97.4	99.2	2.0	0.9941	0.6192	0.1356
ADFI day 26–41,[6] g/bird	184.1	187.6	187.3	186.6	187.4	186.9	187.2	4.3	0.9649	0.9915	0.5416
ADFI day 0–41, g/bird	109.0	109.1	108.9	109.3	109.4	108.9	108.9	2.2	0.9823	0.9545	0.9655
ADG day 0–12, g/bird	29.8	28.8	28.4	28.3	28.4	28.9	28.2	0.3	0.5013	0.2761	0.0199
ADG day 13–25, g/bird	71.9	66.0	65.9	65.8	65.4	66.4	65.9	1.3	0.9924	0.8256	0.0098
ADG day 26–41, g/bird	96.9	94.0	92.7	93.4	94.1	95.0	91.1	1.7	0.8531	0.2706	0.2655
ADG day 0–41, g/bird	66.7	63.6	63.0	63.2	63.3	64.2	62.4	0.9	0.8679	0.3039	0.0330
G:F day 0–12, g:g	0.800	0.774	0.764	0.738	0.756	0.764	0.757	0.021	0.1815	0.9059	0.1126
G:F day 13–25, g:g	0.693	0.676	0.669	0.682	0.677	0.685	0.666	0.014	0.7895	0.5867	0.4638
G:F day 26–41, g:g	0.528	0.501	0.495	0.503	0.504	0.508	0.487	0.009	0.7267	0.1163	0.0388
G:F day 0–41, g:g	0.612	0.584	0.579	0.581	0.580	0.590	0.574	0.010	0.8646	0.2074	0.0097

[a,b]Means within a row and fixed effect without a common superscript differ ($P < 0.05$).
[1]Least squares means based on 6 replicate cages per faba bean treatment and 10 replicate cages for control.
[2]3 × 3 factorial analysis.
[3]Faba bean treatments vs. control.
[4]Starter phase.
[5]Grower phase.
[6]Finisher phase.

faba bean inclusion level reduced ($P < 0.05$) dressing percentage compared with the low and medium levels (74.3 vs. 74.9%; Table 6). Controls were heavier ($P < 0.05$) at slaughter (2,938.4 vs. 2,788.0 g), had heavier ($P < 0.05$) chilled carcasses (2,205.8 vs. 2,084.0 g), and had greater dressing percentage ($P < 0.01$; 75.6 vs. 74.7%) than broilers fed faba bean grain (Table 6). We have recently reported that feeding zero- and high-tannin faba bean cultivars also reduced chilled carcass WT and dressing percentage compared with feeding a wheat–SBM control diet (Cho et al., 2019). The difference in dressing percentage against SBM was small (< 1 percent-point) and would not be of major consequence if the cost of feeding locally grown faba bean was slightly lower than that of imported SBM. Fiber content is known to decrease carcass WT and dressing percentage largely owing to increased gizzard WT and contents (González-Alvarado et al., 2010; Nalle et al., 2010). However, the fiber content between control (9.87% NDF; 4.42% ADF; 4.10% crude fiber) and faba bean (10.10% NDF; 5.08% ADF; 4.35% crude fiber) diets was small. Moreover, Laudadio et al. (2011) showed that BW at day 49 and dressing percentage was not different between broilers fed 31% dehulled and micronized faba bean and those fed the control diet with no faba bean. Therefore, the decreased carcass WT and dressing percentage for broilers fed with faba bean was not likely because of dietary fiber content. Instead, reduced carcass WT and dressing percentage could be due to differences in extent of processing as mentioned earlier; SBM is highly processed compared faba bean that were fed raw, only rolled. Another reason for effects on carcass traits could be due to diet formulation. Faba bean diets were formulated based on the AA digestibility coefficients obtained from the AMINODat 5.0 matrix. Different zero-tannin faba bean cultivars have different AA digestibility values as shown in roosters (Usayran et al., 2014). Therefore, faba bean AA digestibility

Table 6. Effect of feeding 3 zero-tannin faba bean grain cultivars at 3 dietary inclusion levels on antemortem weight (WT), chilled carcass WT, dressing percentage, and yield of saleable meat cuts as percentage of chilled carcass WT of broiler chickens[1] at 42 or 43 days of age[1].

		Cultivar			Inclusion				*P*-value		
Variable	Control	Snowbird	Snowdrop	Tabasco	Low	Medium	High	SEM[2]	Cultivar	Inclusion	Contrast[3]
Antemortem WT, g	2,938.4	2,786.9	2,795.8	2,781.4	2,790.7	2,818.7	2,754.7	60.7	0.9480	0.3690	0.0163
Carcass WT, g	2,205.8	2,071.2	2,087.6	2,093.2	2,095.4	2,123.6	2,032.9	50.2	0.8150	0.0690	0.0230
Dressing, %	75.6	74.7	74.6	74.8	74.9[a]	74.9[a]	74.3[b]	0.3	0.7470	0.0340	0.0088
Saleable cuts, %											
Pectoralis major	31.01	30.68	30.44	30.37	30.62	30.41	30.47	0.47	0.7010	0.8520	0.2972
Pectoralis minor	6.11	6.06	6.07	6.06	6.01	6.05	6.13	0.11	0.9830	0.4170	0.6607
Wings	9.95	10.13	10.07	10.24	10.14	10.14	10.15	0.14	0.2670	0.9950	0.1615
Thighs	16.44	15.80	15.86	15.99	15.86	15.83	15.97	0.33	0.7510	0.8710	0.1037
Drumsticks	12.74	13.22	13.15	13.28	13.21	13.20	13.25	0.24	0.7950	0.9600	0.0314

[a,b]Means within a row and fixed effect without a common superscript differ ($P < 0.05$).
[1]Least squares means based on 6 replicate cages per faba bean treatment and 10 replicate cages for control.
[2]3 × 3 factorial analysis.
[3]Faba bean treatments vs. control.

Table 7. Interaction between feeding zero-tannin faba bean grain cultivar and dietary inclusion level for yield of the *Pectoralis* major muscle as a percentage of chilled carcass weight[1].

	Snowbird			Snowdrop			Tabasco				
Variable	Low	Medium	High	Low	Medium	High	Low	Medium	High	SEM	*P*-value
Pectoralis major, %	31.2[a]	30.3[a,b,c]	30.5[a,b,c]	29.6[c]	30.6[a,b,c]	31.2[a]	31.0[a,b]	30.4[a,b,c]	29.7[b,c]	0.5	0.0489

[a-c]Means within a row without a common superscript differ ($P < 0.05$).
[1]Least squares means based on 6 replicate cages per faba bean treatment.

values may have been overestimated in our study, and this may have resulted in reduced antemortem WT, carcass WT, and dressing percentage in broilers fed faba bean vs. those fed the wheat–SBM diet. These findings highlight the need for further AA digestibility work to maximize inclusion levels of faba bean in broiler diets without affecting carcass traits.

Carcass Cuts

Faba bean cultivar or inclusion level had no effect on the yield of saleable carcass cuts (Table 6). The yield of drumsticks was greater ($P < 0.05$) for broilers fed with faba bean grain than for the controls (13.22 vs. 12.74%, respectively; Table 6) likely because the controls achieved greater antemortem BW. We have previously also reported greater drumstick yield feeding zero- or high-tannin faba bean cultivars than with feeding a wheat–SBM control diet (Cho et al., 2019). There was an interaction between faba bean cultivar and inclusion level for yield of the largest breast muscle *(Pectoralis* major) as the percentage of chilled carcass WT (Table 7); there was no effect of faba bean inclusion levels for cultivars Snowbird and Tabasco, whereas for Snowdrop, the low inclusion level led to birds having lower breast yield percentage than the high inclusion level ($P < 0.05$). In addition, there was no effect of cultivars for the medium inclusion level, whereas birds fed the low inclusion level of Snowdrop showed lower yield for the major breast muscle than birds fed either Snowbird or Tabasco ($P < 0.05$), and for birds fed the high inclusion level, Snowbird showed greater yield of major breast muscles than Tabasco ($P < 0.05$; Table 7). This finding may again be related to not having cultivar-specific AA digestibility coefficients.

Diaz et al. (2006) fed broilers tannin-containing faba bean at an inclusion level of 47.9% (1–10 days of age) and 50% (11–42 days of age). Crude protein levels of all diets were greater in the present study, leading to greater breast yield than that reported by Diaz et al. (2006). The present study, however, found lower dressing percentage by 9 percentage points. The reason for this difference likely relates to how broilers were processed. No differences were found by Diaz et al. (2006) in dressing percentage and leg quarters as percentage compared to their control group. Diaz et al. (2006), however, found 6% greater breast yield in the broilers fed the faba bean treatment than in controls. That was not the case in the present study despite the fact that CP content was greater than that reported by Diaz et al. (2006). Laudadio et al. (2011) fed dehulled and micronized zero-tannin faba bean as replacement for SBM at the 31% inclusion level. This inclusion level did not affect dressing percentage, breast or drumstick yield. Although the design of their study seems comparable to ours, caution should be taken when comparing results of both studies especially regarding the yield of breast as percentage of BW at slaughter. Laudadio et al. (2011) found no effect on breast yield, but breast yield percentage differed largely from that in our study. Their article did not specify how breast muscles (i.e., *Pectoralis* major and minor) were measured. Their findings were about 3% greater minor breast muscle yield than ours. The reason for the difference is not clear but is likely related to differences in the calculation method or breed. Our finding that there was no cultivar or inclusion level effect on the carcass WT, dressing percentage, and yield of saleable cuts indicates that broilers can be progressively fed greater levels up to 40% of the 3 zero-tannin faba bean cultivars tested.

CONCLUSIONS

In conclusion, there was no effect of either faba bean cultivar (Snowbird, Snowdrop, Tabasco) or increasing dietary inclusion level (5, 10, and 20%; 10, 20, and 30%; 15, 30, and 40% for the starter, grower, and finisher phases, respectively) on growth performance, carcass traits, or proportional yield of carcass components. Broiler producers can therefore feed the most aggressive of the 3 inclusion levels tested (15, 30, 40% for the starter, grower, finisher phase) and any of the 3 zero-tannin faba bean cultivars evaluated to maximize faba bean inclusion in broiler diets.

There was no effect on ADFI and there were only slight reductions in BW, ADG, G:F, slaughter WT, chilled carcass WT, and carcass dressing in broilers fed faba bean compared with those fed a wheat–SBM control diet. These differences were attributed to the greater extent of processing to produce SBM vs. feeding raw, merely rolled, faba bean that would be nullified if the cost of feeding locally grown faba bean was lower than that of imported SBM.

ACKNOWLEDGMENTS

This research was funded by Alberta Agriculture and Forestry and Saskatchewan Pulse Growers. The authors thank the Alberta Chicken Producers for the donation of bird quota. The authors acknowledge Ajinomoto and

Halchemix Canada Inc. for donating L-valine. The authors specially thank Brad Goudy, Proactive Producers of Saskatchewan, for his help sourcing the faba bean cultivars.

Conflict of Interest Statement: The authors declare that no financial or other contractual agreements exist that might cause conflicts of interest or be perceived as causing conflicts of interest.

REFERENCES

Alltech. 2018. Alltech Annual Global feed Survey. Accessed Dec. 2019. https://go.alltech.com/hubfs/GFS2018%20Brochure.pdf?hsCtaTracking=a5b7e25c-9ffc-49fa-9155-172c7eb289f7%7C0bb51f65-30c4-40e0-b48b-76a14eacf4d3.

American Society of Agricultural and Biological Engineers. 2008. Methods of Determining and Expressing Fineness of Feed Materials by Sieving. Publ. S319. Am. Soc. Agric. Biol. Eng., St. Joseph, MI.

Ankom Technology. 2017. Analytical methods for fiber analyzer A2000. Accessed Dec. 2019. https://www.ankom.com/analytical-methods-support/fiber-analyzer-a2000.

AOAC. 2016. Official Methods of Analysis of AOAC International. 20th ed. AOAC International, Rockville, MD.

AOCS. 2017. Official Methods and Recommended Practices of the AOCS. 7th ed. American Oil Chemists' Society, Urbana, IL.

Aviagen. 2018. Broiler Ross Management Handbook. Accessed Dec. 2019. http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross-BroilerHandbook2018-EN.pdf.

Aviagen. 2019. Broiler Ross nutrition Specifications. Accessed Dec. 2019. http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/RossBroilerNutritionSpecs2019- EN.pdf.

Canadian Council on Animal Care (CCAC). 2009. CCAC Guidelines on: The Care and Use of Farm Animals in Research, Teaching and Testing. Canadian Council on Animal Care in Science, Ottawa, ON, Canada. Accessed Dec. 2019. https://www.ccac.ca/Documents/Standards/Guidelines/Farm_Animals.pdf.

Cho, M., M. N. Smit, L. He, F. C. Kopmels, and E. Beltranena. 2019. Effect of feeding zero- or high-tannin faba bean cultivars and dehulling on growth performance, carcass traits and yield of saleable cuts of broiler chickens. J. Appl. Poult. Res. 28:1305–1323.

Crépon, K., P. Marget, C. Peyronnet, B. Carrouée, P. Arese, and G. Duc. 2010. Nutritional value of faba bean (*Vicia faba L.*) seeds for feed and food. Field Crops Res. 115:329–339.

Diaz, D., M. Morlacchini, F. Masoero, M. Moschini, G. Fusconi, and G. Piva. 2006. Pea seeds (*Pisum sativum*), faba beans (*Vicia faba* var. *minor*) and lupin seeds (*Lupinus albus* var. *multitalia*) as protein sources in broiler diets: effect of extrusion on growth performance. Ital. J. Anim. Sci. 5:43–53.

Duc, G. 1997. Faba bean (*Vicia faba L.*). Field Crops Res. 53:99–109.

El-Shemy, H., E. Abdel-Rahim, O. Shaban, A. Ragab, E. Carnovale, and K. Fujita. 2000. Comparison of nutritional and antinutritional factors in soybean and faba bean seeds with or without cortex. Soil Sci. Plant Nutr. 46:515–524.

Farrell, D. J., R. A. Perez-Maldonado, and P. E. Mannion. 1999. Optimum inclusion of field peas, faba beans, chick peas and sweet lupins in poultry diets. ii. broiler experiments. Br. Poult. Sci. 40:674–680.

Flores, M. P., J. I. R. Castañon, and J. M. McNab. 1994. Effect of tannins on starch digestibility and TMEn of triticale and semipurified starches from triticale and field beans. Br. Poult. Sci. 35:281–286.

González-Alvarado, J. M., E. Jiménez-Moreno, D. González-Sánchez, R. Lázaro, and G. G. Mateos. 2010. Effect of inclusion of oat hulls and sugar beet pulp in the diet on productive performance and digestive traits of broilers from 1 to 42 days of age. Anim. Feed Sci. Technol. 162:37–46.

Gous, R. M. 2011. Evaluation of faba bean (*Vicia faba* cv. Fiord) as a protein source for broilers.S. Afr. J. Anim. Sci. 41:71–78.

Hejdysz, M., S. A. Kaczmarek, and A. Rutkowski. 2016. Extrusion cooking improves the metabolisable energy of faba beans and the amino acid digestibility in broilers. Anim. Feed Sci. Technol. 212:100–111.

Henriquez, B., M. Olson, C. Hoy, M. Jackson, and T. Wouda. 2018. Frost tolerance of faba bean cultivars (Vicia faba L.) in central Alberta. Can. J. Plant Sci. 98:509–514.

Iji, P. A., K. Khumalo, S. Slippers, and R. M. Gous. 2004. Intestinal function and body growth of broiler chickens on maize-based diets supplemented with mimosa tannins and a microbial enzyme. J. Sci. Food Agric. 84:1451–1458.

Ivarsson, E., and H. Wall. 2017. Effects of toasting, inclusion levels and different enzyme supplementations of faba beans on growth performance of broiler chickens. J. Appl. Poult. Res. 26:467–475.

Jezierny, D., R. Mosenthin, N. Sauer, and M. Eklund. 2010. In vitro prediction of standardised ileal crude protein and amino acid digestibilities in grain legumes for growing pigs. Animal 4:1987–1996.

Köpke, U., and T. Nemecek. 2010. Ecological services of faba bean. Field Crops Res. 115:217–233.

Lacassagne, L., M. Francesch, B. Carré, and J. P. Melcion. 1988. Utilization of tannin-containing and tannin-free faba beans (*Vicia faba*) by young chicks: effects of pelleting feeds on energy, protein and starch digestibility. Anim. Feed Sci. Technol. 20:59–68.

Laudadio, V., E. Ceci, and V. Tufarelli. 2011. Productive traits and meat fatty acid profile of broiler chickens fed diets containing micronized fava beans (*Vicia faba L.* var. minor) as the main protein source. J. Appl. Poult. Res. 20:12–20.

Makkar, H. P. S., K. Becker, H. Abel, and E. Pawelzik. 1997. Nutrient contents, rumen protein degradability and antinutritional factors in some colour- and white-flowering cultivars of Vicia faba beans. J. Sci. Food Agric. 75:511–520.

Nalle, C. L., V. Ravindran, and G. Ravindran. 2010. Nutritional value of faba beans (*Vicia faba L.*) for broilers: apparent metabolisable energy, ileal amino acid digestibility and production performance. Anim. Feed Sci. Technol. 156:104–111.

National Farm Animal Care Council (NFACC). 2016. Code of practice for the care and handling of hatching eggs, breeders, chicken and turkeys. Accessed Dec. 2019. https://www.nfacc.ca/pdfs/codes/poultry_code_EN.pdf.

Nir, I., R. Hillel, G. Shefet, and Z. Nitsan. 1994. Effect of grain particle size on performance. 2. grain texture interactions. Poult. Sci. 73:781–791.

Rada, V., M. Lichovnikova, and I. Safarik. 2017. The effect of soybean meal replacement with raw full-fat soybean in diets for broiler chickens. J. Appl. Poult. Res. 45:112–117.

Regassa, A., and C. Nyachoti. 2018. Application of resistant starch in swine and poultry diets with particular reference to gut health and function. Anim. Nutr. 4:305–310.

SAS Institute. 2017. SAS User Guide. Version 9.4. SAS Institute Inc., Cary, NC.

Sauvant, D., J. Perez, and G. Tran. 2004. Tables of Composition and Nutritional Value of Feed Materials: Pig, Poultry, Sheep, Goats, Rabbits, Horses, and Fish. Wageningen Academic Publishers, Wageningen, the Netherlands.

Schreuder, R., and C. de Visser. 2014. EIP-AGRI Focus Group protein crops: final report. Accessed Dec. 2019. https://ec.europa.eu/eip/agriculture/en/publications/eip-agri-focus-group- protein-crops-final-report.

Strydhorst, S. M., J. R. King, K. J. Lopetinsky, and K. N. Harker. 2008. Forage potential of intercropping barley with faba bean, lupin, or field pea. Agron. J. 100:182–190.

Usayran, N. N., H. Sha'ar, G. W. Barbour, S. K. Yau, F. Maalouf, and M. T. Farran. 2014. Nutritional value, performance, carcass quality, visceral organ size, and blood clinical chemistry of broiler chicks fed 30% tannin-free fava bean diets. Nucleic Acids Res. 93:2018–2027.

Valdebouze, P., E. Bergeron, T. Gaborit, and J. Delort-laval. 1980. Content and distribution of trypsin inhibitors and hemagglutinins in some legume seeds. Can. J. Plant Sci. 60:695–701.

Woyengo, T. A., and C. M. Nyachoti. 2012. Ileal digestibility of amino acids for zero-tannin faba bean (*Vicia faba L.*) fed to broiler chicks. Poult. Sci. 91:439–443.

Wright, K. N. 1981. Soybean meal processing and quality control. J. Am. Oil Chem. Soc. 58:294–300.