Feeding different cultivars and quality levels of faba bean to broiler chickens

Miranda. N. Smit,[†] Liangfei He,[‡] and Eduardo Beltranena[†,‡,1]

[†]Alberta Agriculture and Forestry, Livestock and Crop Research Branch, Edmonton, Alberta, Canada T6H 5T6 [‡]Department of Agricultural, Food and Nutritional Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2P5

ABSTRACT: A concern of both pulse growers and poultry producers is how frost damage around harvest time affects the nutritional quality of faba bean for broiler chickens. To investigate, two zero-tannin cultivars (Snowbird, Snowdrop) and one low vicine and convicine cultivar (Fabelle) sourced from seed growers were spring planted 3 weeks later than recommended (mid-May) and harvested late October to purposely increase frost damage. Parent, certified seed (**high quality**), and harvested frost damaged beans (**low quality**) of the three cultivars were fed to 740 chickens housed in 64 floor pens in a 2 × 3 factorial plus control (9 pens of 11 or 12 birds per treatment). Starter (d 0 to 11), grower (d 12 to 24), and finisher (d 25 to 40) diets included 15%, 30%, and 45% faba bean in partial (starter, grower) or total replacement of soybean meal (**SBM**; control). Harvested Snowbird, Snowdrop, Fabelle averaged 52%, 62%, 17% blackened hull and 35%, 43%, 51% immature beans, respectively. There was a cultivar × quality interaction ($P < 0.05$) on daily feed disappearance (**ADFI**) and gain-to-feed (**G:F**). Broilers fed low-quality Snowdrop consumed 10 g/d more finisher and 6 g/d more feed overall than those fed low-quality Snowbird or Fabelle; broilers fed parent seed were intermediate. Feeding low-quality Fabelle resulted in best overall G:F (0.646) versus high-quality Snowbird (0.611), high-quality Fabelle (0.624), or low-quality Snowdrop (0.624). Average daily weight gain (**ADG**) and bird body weight (**BW**) at the end of each growth phase were not affected by cultivar or quality level. Controls fed SBM only grew 2.75 g/d faster overall and were 113.5 g heavier at the end of the trial than broilers fed faba bean ($P < 0.05$). Controls fed SBM only had 0.024 g/g better overall G:F than broilers fed faba bean ($P < 0.05$). Feeding low-quality beans or high-quality seed had no effect on antemortem BW, chilled carcass weight (**WT**), dressing percentage or yield of saleable cuts except that broilers fed Snowbird or Snowdrop had 0.8%-unit larger thighs than those fed Fabelle. Controls fed SBM only were 110 g heavier at slaughter, had 72 g heavier chilled carcass WT, and 0.5%-unit greater dressing percentage than broilers fed faba bean ($P < 0.05$). These results indicate that feeding frost damaged and(or) immature faba bean, to the extent observed in this trial, did not negatively affect growth performance or carcass attributes of broiler chickens compared to feeding parent, certified, high-quality seed of these cultivars.

Key words: broiler chicken, cultivar, faba bean, frost damage, growth performance, quality

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

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INTRODUCTION

Crop rotation prevents soil nutrient depletion, increases soil microbial activity, and reduces crop specific diseases and pests (Lupwayi and Kennedy, 2007). Field pea is the predominant pulse crop grown in rotation with canola and cereals in Western Canada as heat units limit corn and soybean production in northern latitudes. Faba bean (*Vicia faba* L.) is gaining popularity because it yields more than field pea (>1 tonne/ha) and is the easiest crop to harvest (Faulkner, 1985). Faba bean also fixes the most atmospheric nitrogen compared with all annual legume crops (Hossain et al., 2017). Part of this nitrogen remains in soils increasing the yield of subsequent crops (St. Luce et al., 2015).

Faba bean production is split between that intended for human food and animal feed (Clancey, 2018). The main differences between these markets are first visual quality and second antinutritional factors content. Tannins reduce feed intake, tie up feed protein and starch as well as protein from mucus and gastric secretions (Vilariño et al., 2009). To mitigate, zero-tannin cultivars have been developed (Duc 1997; Crépon et al., 2010) that show greater amino acids digestibility (Woyengo and Nyachoti, 2012). Other relevant antinutritional factors are vicine and convicine that cause hemolytic anemia in humans (favism) with an erythrocyte-located genetic deficiency of glucose-6-phosphate dehydrogenase (Arese et al., 2012). Vicine and convince also reduced layer egg size and increase incidence of blood spots (Muduuli et al., 1981). Their aglycones, divicine, and isouramil, react with blood oxygen forming reactive oxygen species that increase lipid peroxidation. Decreased liver function may result in insufficient bile acid production for micelle formation and lipid digestion reducing energy digestibility (Cho et al., 2019).

Faba bean has a growth cycle >2 weeks longer than field pea making it susceptible to frost. Damaged beans would not make human food export quality but instead would be diverted to animal feeding. Moreover, zero-tannin faba bean cultivars are less tolerant to frost (Henriquez et al, 2018) than tannin cultivars.

Broilers can be fed diets with increasing inclusions of different faba bean cultivars, but previous trials fed high-quality faba bean (up t to 36% Cho et al., 2019; up to 40% Kopmels et al., 2020). More recently, we have shown that planting and harvesting faba bean several weeks later than is considered normal for the region to purposely induce frost damage increased gross energy, crude protein, and amino acid digestibility in broilers possibly by frost interrupting bean ripening (Smit et al., 2021). The current study was conducted to confirm these digestibility findings and evaluate performance. The objective of this study was to compare feeding three faba bean cultivars differing in antinutritional factors content and bean quality level (high [#1 certified seed] vs. low [#2 feed grade, frost damaged and immature beans]) on growth performance, carcass traits, and yield of saleable cuts of broiler chickens. The null hypothesis was that faba bean cultivar and quality level would not affect growth performance, carcass traits, and yield of saleable cuts.

MATERIALS AND METHODS

Animal use was approved, and study procedures were reviewed by the University of Alberta Animal Care and Use Committee for Livestock and followed principles established by the Canadian Council on Animal Care (CCAC, 2009).

Housing

The study was conducted at the Poultry Research and Technology Centre, University of Alberta South Campus (Edmonton, Alberta, Canada). The rectangular room was equipped with four rows of 16 floor level pens each resulting in a total of 64 pens. Pens measured 1.44 × 1.04 m and had layers of newspaper and wood shavings as bedding on top of concrete flooring. One pen side wall was made of concrete blocks and the other three side walls were plastic mesh strung around frames made of polyvinyl chloride piping. Birds in each pen were given access to a water dish, a rectangular feeding trough, a height-adjustable round feeder hanging from the ceiling and a height-adjustable bar with three to four nipple drinkers. Parchment paper was initially placed on the pen floor with test feed sprinkled on top next to the rectangular feeding trough to encourage consumption. The water dish, parchment paper and rectangular feeding trough were removed after day (**d**) 6.

Controllers and timers specific to the test room adjusted temperature, ventilation, and lighting. The temperature of the room was reduced as birds aged as per the Ross 708 production manual (Aviagen, 2018) adjusted for low air relative humidity. Lightning schedule in the windowless barn conformed to the National Farm Animal Care Council Code of Practice (**NFACC**; 2016). Broilers were provided a minimum of 10 to 15 lux with 20 hours (**h**) of lights on:4 h off throughout the trial. The chimney ventilation system exhausted warm air using ceiling vents, drawing cold air into the room from the attic through the barn side soffits creating negative airflow.

Ingredients and Diets

Cleaned, #1 certified seed (**high quality**) of three different faba bean cultivars was sourced. Zero-tannin Snowbird originated from Galloway Seeds (Fort Saskatchewan, Alberta, Canada), zero-tannin Snowdrop from Shewchuk Seeds (Blaine Lake, Saskatchewan, Canada), and tannin, low vicine and convicine Fabelle was sourced from Stamp Seeds (Enchant, Alberta, Canada). One-half of the parent, high-quality seed for each cultivar was planted at a single site (53°38′52.2″ N 113°21′09.2″) at the Crop Diversification Centre North (Edmonton, Alberta, Canada). Seeding (mid May 2019) and desiccating (early October) were conducted late to purposely increase the proportion of frost-damaged and immature beans at harvest (late October) resulting in feed grade (**low quality**) beans. These low-quality faba beans were cleaned using a combination of mesh sieving and blowing air in a custom-made, pilot-scale seed cleaner at the University of Alberta Environmental and Metabolism Research Centre (Edmonton, Alberta, Canada). Table 1 shows the analyzed nutrient content of the different faba bean cultivars and quality levels, as well as other main feedstuffs fed to broilers in this trial. Whole grain ingredients (faba bean, wheat, canola seed [*Brassica napus*]) 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 Process Equipment Ltd., Ajax, Ontario, Canada). 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.

Animals and Experiment Design

In total, 740 male Ross 708 broiler chickens (Lilydale hatchery, Spruce Grove, Alberta, Canada) originating from the same flock and hatched on the same day were involved in the experiment. Chicks were individually weighed promptly after arrival and randomly distributed among 64 floor pens, 11 or 12 chicks per pen (initial body weight [**BW**] 41.1 ± 4.6 g), above minimum space requirements as set forth in the NFACC (2016) animal care guidelines. The 64 pens were divided into nine area blocks by location along the rectangular test room.

In total, seven different dietary regimens were fed. Each dietary regimen appeared once in each block for a randomized complete block design with nine replicate pens per dietary regimen. Birds in the remaining pen were fed the control regimen resulting in 10 replicates for the control. Dietary regimens were fed over three phases (starter, d 0 to 11; grower, d 12 to 24; and finisher, d 25 to 40) for the entire 40-d growth cycle. The control regimen was a wheat grain-soybean (**SBM**) based diet like

Table 1. Analyzed nutrient content, particle size, and gross energy (GE) of main diet feedstuffs, antinutritional factor content, and subjective proportion of frost damage and immature faba bean of the three cultivars planted (as-is basis)

	Faba bean							Canola seed		
	Snowbird High[1]	Snowdrop High[2]	Fabelle High[3]	Snow-bird Low[4]	Snow-drop Low[4]	Fabelle Low[4]	Soybean meal	Batch 1[5]	Batch 2[6]	Wheat CPS white
Nutrient, %										
Moisture	13.21	8.67	9.19	10.76	10.77	11.13	8.26	4.61	7.86	14.75
Starch	34.53	36.50	33.12	37.36	30.96	34.57	NA[7]	NA	NA	46.50
Crude protein	26.31	26.14	29.22	26.30	26.23	27.63	44.37	22.69	18.23	14.20
NDF[8]	9.70	10.68	11.02	9.59	13.32	9.28	8.13	14.99	16.61	6.91
ADF[9]	8.77	10.16	9.01	8.42	10.09	8.13	5.32	12.75	14.43	3.32
Crude fiber	7.72	7.91	6.24	6.51	7.64	5.86	3.80	7.25	8.03	1.63
Ash	2.80	2.98	3.03	3.34	3.38	3.07	6.27	3.65	3.62	1.48
Crude fat	0.51	0.04	0.14	0.65	1.14	1.33	3.20	43.87	44.68	0.33
Indispensable AA										
Arginine	2.27	2.26	2.81	2.01	2.18	2.50	3.16	1.46	1.18	0.61
Histidine	0.66	0.66	0.74	0.62	0.63	0.69	1.17	0.63	0.50	0.31
Isoleucine	1.15	1.11	1.25	1.12	1.11	1.22	2.15	0.96	0.77	0.49

Table 1. Continued

	Faba bean							Canola seed		
	Snowbird High[1]	Snowdrop High[2]	Fabelle High[3]	Snow-bird Low[4]	Snow-drop Low[4]	Fabelle Low[4]	Soybean meal	Batch 1[5]	Batch 2[6]	Wheat CPS white
Leucine	1.95	1.91	2.18	1.89	1.91	2.09	3.45	1.58	1.32	0.94
Lysine	1.65	1.65	1.84	1.64	1.63	1.76	2.83	1.38	1.13	0.38
Methionine	0.17	0.17	0.20	0.18	0.19	0.19	0.61	0.45	0.36	0.19
Phenylalanine	1.13	1.11	1.26	1.14	1.13	1.23	2.32	0.93	0.77	0.65
Threonine	0.87	0.89	0.99	0.85	0.87	0.92	1.70	0.96	0.84	0.38
Tryptophan	0.21	0.20	0.20	0.19	0.20	0.17	0.61	0.19	0.17	0.15
Valine	1.23	1.22	1.40	1.23	1.23	1.36	2.28	1.25	1.00	0.59
Dispensable AA										
Alanine	1.03	1.06	1.20	1.18	1.18	1.20	1.93	0.94	0.79	0.45
Aspartic acid	2.79	2.74	3.15	2.70	2.70	2.93	4.96	1.58	1.38	0.66
Cysteine	0.30	0.34	0.36	0.29	0.31	0.32	0.63	0.59	0.47	0.30
Glutamic acid	4.31	4.15	4.87	4.12	4.15	4.61	7.92	3.52	2.79	4.54
Glycine	1.10	1.12	1.23	1.04	1.08	1.14	1.89	1.10	0.92	0.58
Proline	1.08	1.04	1.22	1.04	1.05	1.16	2.26	1.34	1.03	1.42
Serine	1.03	1.03	1.19	1.04	1.04	1.08	1.83	0.80	0.73	0.60
Taurine	0.14	0.15	0.14	0.13	0.14	0.14	0.08	0.04	0.05	0.15
Tyrosine	0.82	0.82	0.93	0.79	0.84	0.86	1.64	0.69	0.54	0.39
Total AA	24.05	23.75	27.28	23.51	23.88	25.79	43.71	20.92	17.18	13.92
Particle size, µm	1,090	1,147	1,125	1,098	1,046	1,012	686	604	NA	1,111
St. Dev., µm	1.92	1.80	1.89	1.96	1.98	2.16	1.84	1.83	NA	2.21
Gross energy, MJ/kg	15.37	15.72	15.75	16.41	16.57	16.92	16.88	27.16	26.74	14.96
Proanthocyanidins, g/kg[10]	ND[11]	ND	6.38	ND	0.27	6.49	NA	NA	NA	NA
Degree of polymerization	-	-	5.19	-	6.85	5.51	NA	NA	NA	NA
Vicine, g/kg	5.12	5.78	0.41	4.23	4.56	0.46	NA	NA	NA	NA
St. Dev., g/kg	0.22	0.36	0.02	0.19	0.32	0.03	NA	NA	NA	NA
Convicine, g/kg	3.29	3.89	0.17	2.53	3.01	0.24	NA	NA	NA	NA
St. Dev., g/kg	0.21	0.24	0.01	0.06	0.18	0.01	NA	NA	NA	NA
Bulk density, g/L	794	808	722	737	730	650				
Frost damage[12], %										
High				16	14	3				
Intermediate				36	49	14				
No/low	100	100	100	49	38	83				
Maturity[13], %										
Immature				35	43	51				
Ripe	100	100	100	66	57	49				

[1]High quality (#1 certified seed) sourced from Galloway Seeds (Fort Saskatchewan, Alberta, Canada).

[2]High quality (#1 certified seed) sourced from Shewchuk Seeds (Blaine Lake, Saskatchewan, Canada).

[3]High quality (#1 certified seed) sourced from Stamp Seeds (Enchant, Alberta, Canada).

[4]Low quality (feed grade) grown at the Crop Diversification Centre North (Edmonton, Alberta, Canada).

[5]Fed in the starter (d 0 to11) and grower phase (d 12 to 24).

[6]Fed in the finisher phase (d 25 to 40).

[7]Not analyzed.

[8]Neutral detergent fiber.

[9]Acid detergent fiber.

[10]Condensed tannins plus monomeric flavan-3-ols.

[11]Not detected (≤0.05 g/kg).

[12] To quantify frost damage, samples were spread on a tabletop, 100 beans were separated by riffle cuts as conducted in grain grading and the number of beans that had high (blackened hull), intermediate, low or no damage were counted.

[13]The same 100 beans were broken apart (cut through) and marked as immature if the cotyledons were green and soft when rolled, or normal if they were yellowish or white and hard.

what is commonly fed to broiler chickens in the commercial industry in Western Canada (Tables 2, 3, and 4). Test dietary regimens included two different zero-tannin (Snowbird and Snowdrop) and 1 tannin, low vicine and convicine faba bean cultivar (Fabelle) of two different quality levels (high-quality seed or low-quality beans) fed at increasing inclusions by growth phase (15%, 30%, and 45% for starter, grower and finisher phase, respectively). Faba bean replaced SBM either partially (starter, grower) or totally (finisher) and wheat grain in phase diets. Diets were formulated without antimicrobials or coccidiostat to provide 12.5, 12.8, and 13.1 megajoules (**MJ**) AME_n/kilogram (**kg**) and 1.0, 0.9, and 0.8 g standardized ileal digestible (**SID**) lysine/MJ AME_n in the starter, grower, and finisher phases, respectively. For faba bean, proximate and amino acid (**AA**) content were based on actual lab results whereas SID AA were taken from AMINOD at 5.0 (Evonik Degussa GmbH; Hanau-Wolfgang, Germany). The AME_n value of faba bean cultivars was assumed to be 10 MJ AME_n/kg based on Sauvant et al. (2004). Other AA were formulated as ideal ratio to lysine and exceeded nutrient recommendations.

Measurements and Calculations

Individual broiler BW, the amount of feed added to each pen feeder during each growth phase, and orts remaining at the end were weighed on d 0, 11, 24, and 40 to calculate average daily gain (**ADG**), average daily feed disappearance (**ADFI**), and gain-to-feed ratio (**G:F**; ADG/ADFI). Throughout the trial, broilers found dead, ill, or injured were promptly removed, euthanized, individually weighed, and the suspect reason for death or removal was written down. Late afternoon on d 40 or 41, broilers were removed from pens, individually weighed, wing-banded, crated, and transported (~500 m) to the site abattoir. They had no access to feed or water overnight. Broilers were slaughtered early the following morning and processed following typical commercial procedures (d 41 or 42 of age). Antemortem weight was taken before stunning and bleeding out each bird. Broilers were then scalded, defeathered, and eviscerated. Washed carcasses were blast-chilled to 4 °C measured in breast and individually weighed to calculate dressing percentage. Five randomly selected carcasses per pen were then broken down into saleable cuts (breast, thighs, drumsticks, wings, and trim) and weighed to calculate yield relative to chilled carcass weight.

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 for dry matter (**DM**; method 934.01), crude protein (**CP**; method 990.03), AA (method 982.30 E (a, b, c)), crude fat (method 920.39 (A)), ash (method 942.05), crude fiber (method 978.10), acid detergent fiber (**ADF**; method 973.18 (A-D)), neutral detergent fiber (**NDF**; Holst, 1973), and starch (assay kit STA-20; Sigma, St. Louis, MO) content using the Association of Official Analytical Chemists (AOAC, 2006) methods at the Agricultural Experiment Station Chemical Laboratories (University of Missouri, Columbia, MO). Gross energy (**GE**) for feedstuffs and diet samples was measured in duplicates by bomb calorimetry (Model 6050, Parr Instrument Company, Moline, IL) using benzoic acid as a standard. Feed ingredient and diet particle size was determined using a mechanical sieve shaker (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). To quantify frost damage, samples were spread on a tabletop, 100 beans were separated by riffle cuts as conducted in grain grading and the number of beans that had high (blackened hull), intermediate, low or no damage were counted. The same 100 beans were broken apart (cut through) and marked as immature if the cotyledons were green and soft when rolled, or normal if they were yellowish or white and hard.

Faba bean samples were also analyzed at the Natural Resources Institute Finland (LUKE; Jokioinen, Finland) for proanthocyanidins (mostly condensed tannin [**CT**] plus some monomeric flavan-3-ols) using HPLC after thiolytic degradation, as described by Ivarsson and Neil (2018).

Faba bean samples were analyzed for vicine and convicine content using a slight modification of the extraction procedure described by Purves et al. (2018) at the Organic Residue Laboratory, Alberta Agriculture and Forestry (Edmonton, Alberta, Canada), as described in more detail by Cho et al. (2019).

Table 2. Ingredient composition, analyzed nutrient content (standardized to 10% moisture), particle size, and gross energy (GE) value of starter phase diets fed from day 0 to 11

	Control	Snowbird High	Snowdrop High	Fabelle High	Snowbird Low	Snowdrop Low	Fabelle Low
Ingredients, %							
Wheat CPS white, rolled	56.74	45.83	45.83	45.83	45.83	45.83	45.83
Soybean meal	20.00	15.00	15.00	15.00	15.00	15.00	15.00
Snowbird, #1 certified seed[1]		15.00					
Snowdrop, #1 certified seed[2]			15.00				
Fabelle, #1 certified seed[3]				15.00			
Snowbird, #2 feed grade[4]					15.00		
Snowdrop, #2 feed grade[4]						15.00	
Fabelle, #2 feed grade[4]							15.00
Canola seed, rolled	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Fish meal	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Canola oil	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Broiler premix[5]	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
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Mono/dicalcium phosphate	0.30	0.20	0.20	0.20	0.20	0.20	0.20
L-Lysine HCl	0.30	0.30	0.30	0.30	0.30	0.30	0.30
DL-Methionine	0.30	0.30	0.30	0.30	0.30	0.30	0.30
L-Threonine	0.30	0.30	0.30	0.30	0.30	0.30	0.30
L-Valine	0.11	0.12	0.12	0.12	0.12	0.12	0.12
Choline chloride 60%	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Superzyme Plus[6]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Analyzed nutrient content, %							
Crude protein	27.53	27.18	27.04	27.50	26.60	26.92	26.40
Crude fat	6.75	7.65	7.24	7.35	6.92	7.37	6.81
Crude fiber	2.30	2.84	2.88	2.78	2.98	2.97	2.92
Ash	6.48	6.20	6.15	6.10	6.14	6.15	5.82
Calcium	1.26	1.18	1.16	1.16	1.16	1.19	0.98
Phosphorus	0.80	0.76	0.76	0.76	0.79	0.77	0.73
Indispensable AA							
Arginine	1.60	1.66	1.65	1.74	1.64	1.64	1.65
Histidine	0.66	0.64	0.63	0.66	0.63	0.64	0.62
Isoleucine	1.13	1.10	1.09	1.13	1.11	1.10	1.07
Leucine	1.91	1.86	1.85	1.91	1.88	1.85	1.84
Lysine	1.83	1.77	1.76	1.85	1.77	1.76	1.74

Table 2. Continued

	Control	Snowbird High	Snowdrop High	Fabelle High	Snowbird Low	Snowdrop Low	Fabelle Low
Methionine	0.75	0.68	0.75	0.77	0.73	0.83	0.66
Phenylalanine	1.22	1.17	1.16	1.19	1.18	1.15	1.15
Threonine	1.22	1.17	1.17	1.23	1.22	1.17	1.20
Tryptophan	0.32	0.28	0.27	0.28	0.28	0.29	0.27
Valine	1.42	1.37	1.37	1.43	1.39	1.37	1.34
Dispensable AA							
Alanine	1.20	1.17	1.17	1.19	1.20	1.19	1.15
Aspartic acid	2.26	2.26	2.24	2.37	2.31	2.26	2.21
Cysteine	0.42	0.40	0.40	0.42	0.40	0.41	0.39
Glutamic acid	5.38	5.01	4.98	5.15	4.99	5.00	5.04
Glycine	1.32	1.29	1.30	1.31	1.28	1.29	1.26
Proline	1.75	1.58	1.57	1.57	1.59	1.55	1.58
Serine	0.98	0.96	0.96	1.01	0.98	0.97	0.98
Taurine	0.15	0.14	0.15	0.14	0.15	0.16	0.15
Tyrosine	0.84	0.83	0.82	0.82	0.83	0.81	0.81
Total AA	26.63	25.58	25.57	26.46	25.87	25.68	25.41
Gross energy, MJ/kg	17.74	17.92	17.81	17.79	17.60	17.82	18.05
Particle size, µm	850	850	834	871	919	785	905
St. Dev., µm	2.04	2.06	2.07	2.18	2.05	2.26	2.13

[1]High quality (#1 certified seed) sourced from Galloway Seeds (Fort Saskatchewan, Alberta, Canada).

[2]High quality (#1 certified seed) sourced from Shewchuk Seeds (Blaine Lake, Saskatchewan, Canada).

[3]High quality (#1 certified seed) sourced from Stamp Seeds (Enchant, Alberta, Canada).

[4]Low quality (feed grade) grown at the Crop Diversification Centre North (Edmonton, Alberta, Canada).

[5]Trouw Nutrition (Ponoka, Alberta, Canada). Provided the following per kg of feed: vitamin D3 (vitamin D3 500), 4,000 IU; vitamin A (vitamin A 1000), 10,000 IU; vitamin E (vitamin E 500), 50 IU; thiamine (thiamine monohydrate 99%), 4 mg; riboflavin (riboflavin 80%), 10 mg; pantothenic acid (calcium pantothenate 98%), 15 mg; biotin (biotin 2% premix), 0.2 mg; folic acid (folic acid 98%), 2 mg; vitamin B12 (vitamin B12 0.1% premix), 0.02 mg; niacin (niacin 99%), 65 mg; vitamin K (vitamin K3 [MNB] 43%), 4 mg; pyridoxine (pyridoxine 99%), 5 mg; manganese (manganous oxide 60%), 120 mg; iron (ferrous sulfate 30%), 80 mg; copper (copper sulfate 25%), 20 mg; zinc (zinc oxide 72%), 100 mg; selenium (Selplex 2000), 0.3 mg; iodine (EDDI), 1.65 mg.

[6]Canadian Bio-Systems Inc. (Calgary, Alberta, Canada). Provided the following enzyme activity per kg of feed: xylanase, 1,200 U; glucanase, 150 U; invertase, 700 U; protease, 1,200 U; cellulase, 500 U; amylase, 12,000 U; mannase, 60 U; phytase, 1,000 U.

Table 3. Ingredient composition, analyzed nutrient content (standardized to 10% moisture), particle size, and gross energy (GE) value of grower phase diets fed from day 12 to 24

	Control	Snowbird High	Snowdrop High	Fabelle High	Snowbird Low	Snowdrop Low	Fabelle Low
Ingredients, %							
Wheat CPS white, rolled	56.92	34.70	34.70	34.70	34.70	34.70	34.70
Soybean meal	20.00	10.00	10.00	10.00	10.00	10.00	10.00
Snowbird, #1 certified seed[1]		30.00					
Snowdrop, #1 certified seed[2]			30.00				
Fabelle, #1 certified seed[3]				30.00			
Snowbird, #2 feed grade[4]					30.00		
Snowdrop, #2 feed grade[4]						30.00	
Fabelle, #2 feed grade[4]							30.00
Canola seed, rolled	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Fish meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Canola oil	0.00	2.17	2.17	2.17	2.17	2.17	2.17
Limestone	0.65	0.70	0.70	0.70	0.70	0.70	0.70
Broiler premix[5]	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Sodium bicarbonate	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Mono/dicalcium phosphate	0.30	0.20	0.20	0.20	0.20	0.20	0.20
L-Lysine HCl	0.32	0.30	0.30	0.30	0.30	0.30	0.30
DL-Methionine	0.25	0.35	0.35	0.35	0.35	0.35	0.35
L-Threonine	0.30	0.30	0.30	0.30	0.30	0.30	0.30
L-Valine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
L-Tryptophan	0.05	0.07	0.07	0.07	0.07	0.07	0.07
Choline chloride 60%	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Superzyme Plus[6]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Analyzed nutrient content, %							
Crude protein	25.46	24.35	24.87	25.49	25.07	24.94	25.02
Crude fat	8.36	10.04	9.97	10.15	10.33	10.24	10.15
Crude fiber	2.53	3.49	4.98	3.74	3.65	4.18	3.79
Ash	5.52	5.08	5.10	5.15	5.37	5.23	5.09
Calcium	0.93	0.83	0.86	0.84	0.86	0.84	0.84
Phosphorus	0.67	0.56	0.60	0.58	0.64	0.63	0.60
Indispensable AA							
Arginine	1.48	1.65	1.64	1.80	1.58	1.58	1.73
Histidine	0.60	0.59	0.59	0.62	0.59	0.59	0.60
Isoleucine	1.03	1.04	1.02	1.04	1.03	0.99	1.03
Leucine	1.76	1.76	1.72	1.78	1.74	1.70	1.77

Table 3. Continued

	Control	Snowbird High	Snowdrop High	Fabelle High	Snowbird Low	Snowdrop Low	Fabelle Low
Lysine	1.64	1.64	1.64	1.71	1.68	1.63	1.69
Methionine	0.68	0.68	0.70	0.72	0.69	0.68	0.62
Phenylalanine	1.13	1.08	1.04	1.10	1.07	1.05	1.09
Threonine	1.15	1.13	1.14	1.13	1.11	1.15	1.16
Tryptophan	0.34	0.30	0.31	0.31	0.31	0.32	0.31
Valine	1.30	1.30	1.26	1.29	1.26	1.25	1.30
Dispensable AA							
Alanine	1.05	1.04	1.02	1.05	1.07	1.06	1.07
Aspartic acid	2.07	2.14	2.12	2.23	2.13	2.05	2.18
Cysteine	0.42	0.39	0.38	0.38	0.37	0.36	0.39
Glutamic acid	5.10	4.57	4.47	4.69	4.55	4.46	4.69
Glycine	1.14	1.13	1.12	1.15	1.13	1.11	1.13
Hydroxylysine	0.05	0.04	0.04	0.04	0.08	0.08	0.05
Hydroxyproline	0.16	0.16	0.14	0.16	0.20	0.14	0.15
Lanthionine	0.05	0.05	0.04	0.05	0.04	0.05	0.04
Ornithine	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Proline	1.67	1.43	1.40	1.43	1.39	1.40	1.44
Serine	0.95	0.89	0.90	0.93	0.94	0.89	0.95
Taurine	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Tyrosine	0.78	0.77	0.75	0.77	0.77	0.76	0.78
Total AA	24.72	23.93	23.59	24.53	23.87	23.46	24.31
Gross energy, kcal/kg	4,064.8	4,472.0	4,159.3	4,443.8	4,176.0	4,157.1	4,468.6
Particle size, µm	1,307	1,275	1,188	1,244	1,169	1,205	1,225
St. Dev., µm	2.13	2.02	2.00	2.01	2.04	2.02	2.03

[1]High quality (#1 certified seed) sourced from Galloway Seeds (Fort Saskatchewan, Alberta, Canada).

[2]High quality (#1 certified seed) sourced from Shewchuk Seeds (Blaine Lake, Saskatchewan, Canada).

[3]High quality (#1 certified seed) sourced from Stamp Seeds (Enchant, Alberta, Canada).

[4]Low quality (feed grade) grown at the Crop Diversification Centre North (Edmonton, Alberta, Canada).

[5]Trouw Nutrition (Ponoka, Alberta, Canada). Provided the following per kg of feed: vitamin D3 (vitamin D3 500), 3,200 IU; vitamin A (vitamin A 1000), 8,000 IU; vitamin E (vitamin E 500), 40 IU; thiamine (thiamine monohydrate 99%), 3.2 mg; riboflavin (riboflavin 80%), 8 mg; pantothenic acid (calcium pantothenate 98%), 12 mg; biotin (biotin 2% premix), 0.16 mg; folic acid (folic acid 98%), 1.6 mg; vitamin B12 (vitamin B12 0.1% premix), 0.016 mg; niacin (niacin 99%), 52 mg; vitamin K (vitamin K3 [MNB] 43%), 3.2 mg; pyridoxine (pyridoxine 99%), 4 mg; manganese (manganous oxide 60%), 96 mg; iron (ferrous sulfate 30%), 64 mg; copper (copper sulfate 25%), 16 mg; zinc (zinc oxide 72%), 80 mg; selenium (Selplex 2000), 0.24 mg; iodine (EDDI), 1.32 mg.

[6]Canadian Bio-Systems Inc. (Calgary, Alberta, Canada). Provided the following enzyme activity per kg of feed: xylanase, 1,200 U; glucanase, 150 U; invertase, 700 U; protease, 1,200 U; cellulase, 500 U; amylase, 12,000 U; mannase, 60 U; phytase, 1,000 U.

Table 4. Ingredient composition, analyzed nutrient content (standardized to 10% moisture), particle size, and gross energy (GE) value of finisher phase diets fed from day 25 to 40

	Control	Snowbird High	Snowdrop High	Fabelle High	Snowbird Low	Snowdrop Low	Fabelle Low
Ingredients, %							
Wheat CPS white, rolled	56.67	28.92	28.92	28.92	28.92	28.92	28.92
Soybean meal	20.00						
Snowbird, #1 certified seed[1]		45.00					
Snowdrop, #1 certified seed[2]			45.00				
Fabelle, #1 certified seed[3]				45.00			
Snowbird, #2 feed grade[4]					45.00		
Snowdrop, #2 feed grade[4]						45.00	
Fabelle, #2 feed grade[4]							45.00
Canola seed, rolled	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Canola oil	0.00	2.50	2.50	2.50	2.50	2.50	2.50
Limestone	1.00	1.15	1.15	1.15	1.15	1.15	1.15
Broiler premix[5]	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Sodium bicarbonate	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Mono/dicalcium phosphate	0.40	0.30	0.30	0.30	0.30	0.30	0.30
L-Lysine HCl	0.30	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.15	0.30	0.30	0.30	0.30	0.30	0.30
L-Threonine	0.25	0.30	0.30	0.30	0.30	0.30	0.30
L-Valine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
L-Tryptophan	0.05	0.10	0.10	0.10	0.10	0.10	0.10
Choline chloride 60%	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Superzyme Plus[6]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Analyzed nutrient content, %							
Crude protein	22.19	21.41	20.60	21.86	20.32	20.62	21.12
Crude fat	10.44	12.01	12.13	12.16	13.38	12.64	12.99
Crude fiber	3.29	4.75	5.24	4.46	4.88	5.87	4.74
Ash	4.87	4.37	4.45	4.55	4.74	4.47	4.42
Calcium	0.75	0.79	0.75	0.79	0.84	0.79	0.76
Phosphorus	0.56	0.42	0.47	0.46	0.52	0.53	0.49
Indispensable AA							
Arginine	1.28	1.53	1.44	1.74	1.31	1.40	1.57
Histidine	0.54	0.50	0.49	0.54	0.47	0.49	0.50
Isoleucine	0.90	0.85	0.78	0.88	0.80	0.81	0.86

Table 4. Continued

	Control	Snowbird High	Snowdrop High	Fabelle High	Snowbird Low	Snowdrop Low	Fabelle Low
Leucine	1.55	1.49	1.39	1.53	1.37	1.38	1.48
Lysine	1.33	1.35	1.26	1.41	1.30	1.32	1.36
Methionine	0.47	0.50	0.49	0.52	0.50	0.45	0.51
Phenylalanine	1.02	0.89	0.84	0.91	0.84	0.84	0.89
Threonine	1.01	0.94	0.93	1.04	0.95	1.01	0.95
Tryptophan	0.32	0.29	0.26	0.25	0.30	0.27	0.25
Valine	1.13	1.07	1.01	1.12	1.01	1.04	1.08
Dispensable AA							
Alanine	0.85	0.80	0.77	0.85	0.79	0.81	0.84
Aspartic acid	1.76	1.86	1.72	1.94	1.65	1.69	1.83
Cysteine	0.41	0.35	0.33	0.34	0.30	0.32	0.32
Glutamic acid	4.80	4.01	3.75	4.05	3.65	3.72	3.98
Glycine	0.93	0.89	0.86	0.91	0.82	0.84	0.88
Hydroxylysine	0.03	0.03	0.03	0.03	0.07	0.07	0.05
Hydroxyproline	0.10	0.07	0.11	0.08	0.06	0.07	0.08
Lanthionine	0.05	0.04	0.03	0.04	0.04	0.04	0.04
Ornithine	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Proline	1.51	1.16	1.17	1.17	1.10	1.12	1.17
Serine	0.86	0.82	0.77	0.80	0.73	0.75	0.79
Taurine	0.12	0.13	0.14	0.13	0.13	0.13	0.13
Tyrosine	0.70	0.65	0.62	0.67	0.60	0.60	0.63
Total AA	21.64	20.21	19.18	20.94	18.77	19.14	20.19
Gross energy, MJ/kg	18.29	18.90	17.47	18.76	18.69	18.95	19.15
Particle size, µm	1,043	1,080	1,164	1,168	1,322	1,313	1,257
St. Dev., µm	2.09	1.89	1.82	1.89	1.85	1.81	1.88

[1]High quality (#1 certified seed) sourced from Galloway Seeds (Fort Saskatchewan, Alberta, Canada).

[2]High quality (#1 certified seed) sourced from Shewchuk Seeds (Blaine Lake, Saskatchewan, Canada).

[3]High quality (#1 certified seed) sourced from Stamp Seeds (Enchant, Alberta, Canada).

[4]Low quality (feed grade) grown at the Crop Diversification Centre North (Edmonton, Alberta, Canada).

[5]Trouw Nutrition (Ponoka, Alberta, Canada). Provided per kg of feed: vitamin D3 (vitamin D3 500), 2,400 IU; vitamin A (vitamin A 1000), 6,000 IU; vitamin E (vitamin E 500), 30 IU; thiamine (thiamine monohydrate 99%), 2.4 mg; riboflavin (riboflavin 80%), 6 mg; pantothenic acid (calcium pantothenate 98%), 9 mg; biotin (biotin 2% premix), 0.12 mg; folic acid (folic acid 98%), 1.2 mg; vitamin B12 (vitamin B12 0.1% premix), 0.012 mg; niacin (niacin 99%), 39 mg; vitamin K (vitamin K3 [MNB] 43%), 2.4 mg; pyridoxine (pyridoxine 99%), 3 mg; manganese (manganous oxide 60%), 72 mg; iron (ferrous sulfate 30%), 48 mg; copper (copper sulfate 25%), 12 mg; zinc (zinc oxide 72%), 60 mg; selenium (Selplex 2000), 0.18 mg; iodine (EDDI), 0.99 mg.

[6]Canadian Bio-Systems Inc. (Calgary, Alberta, Canada). Provided the following enzyme activity per kg of feed: xylanase, 1,200 U; glucanase, 150 U; invertase, 700 U; protease, 1,200 U; cellulase, 500 U; amylase, 12,000 U; mannase, 60 U; phytase, 1,000 U.

Statistical Analyses

Data residuals were tested for normality using the Univariate procedure of SAS Ver 9.4 (SAS Institute, Cary, NC). Growth performance, carcass traits, and yield of saleable cuts data were analyzed with a generalized linear mixed model (GLIMMIX procedure) using a normal distribution and the identity link function. Growth performance variables were analyzed for each growth phase and for the overall trial. Pen was the experimental unit for all growth performance and carcass variables, and individual carcass was the sampling unit for carcass data. Data were analyzed as a 3 (Snowbird, Snowdrop, Fabelle) × 2 (high quality, low quality) factorial and included a contrast statement comparing all faba bean diets to the control diet. Block was the random term in all models. Mean separation was performed using the PDIFF option in the LSMEANS statement. Treatment differences were considered significant if $P < 0.05$.

RESULTS

Nutrient Content

Snowbird faba bean averaged 3%-unit greater starch and 1%-unit lower NDF and ADF content than Snowdrop or Fabelle (Table 1). In contrast, Fabelle averaged 2%-unit greater CP and 2.5%-unit great AA content than Snowbird or Snowdrop. As expected, Fabelle had greater CT but lower vicine and convicine content than Snowbird or Snowdrop. Harvested, low-quality beans averaged 7% greater GE value than the parent, high-quality seed planted in spring. Harvested Snowbird, Snowdrop, and Fabelle averaged 52%, 62%, and 17% blackened hull and 35%, 43%, and 51% immature beans, respectively.

For all feeding phases, and as expected, both crude fat and crude fiber content were greater for faba bean than control diets (Tables 2, 3, and 4). In general, CP content was somewhat lower in faba bean diets compared with control.

Growth Performance

There was no effect of feeding either faba bean cultivar or quality level on broiler BW, ADG and ADFI at the end of each growth phase except for the grower phase. Broilers fed Fabelle had greater ($P < 0.05$) ADG than those fed Snowbird; Snowdrop was intermediate (Table 5). There was a faba bean cultivar × quality level interaction ($P < 0.05$) on finisher phase and overall ADFI. Broilers fed low-quality Snowdrop consumed 10 g/d more Finisher and 6 g/d more feed overall than those fed low-quality Snowbird or Fabelle; broilers fed high-quality seed were intermediate (Table 6). For the grower phase, broilers fed Fabelle had greater G:F than those fed Snowbird; Snowdrop was intermediate. For the grower phase too, G:F was greater for broilers fed low-quality beans versus high-quality seed (Table 5). For the overall trial, there was a faba bean cultivar × quality level interaction ($P < 0.05$) on G:F. Broilers fed low-quality Fabelle, low-quality Snowbird or high-quality Snowdrop had greater G:F than those fed high-quality Snowbird; high-quality Fabelle or low-quality Snowdrop were intermediate (Table 6).

Controls fed SBM only grew 6.24 g/d faster during the finisher phase and 2.75 g/d faster overall and were 113.5 g heavier at the end of the trial than broilers fed faba bean ($P < 0.05$; Table 5). Throughout the trial, ADFI was not different between broilers fed faba bean versus control diets. Controls fed SBM only had 0.035, 0.031, and 0.024 g/g greater ($P < 0.01$) G:F for the starter phase, finisher phase, and overall, respectively, than broilers fed faba bean diets.

Carcass Characteristics and Yield of Cuts

There was no effect of feeding either faba bean cultivar or quality level on antemortem live BW, chilled carcass weight (**WT**), dressing percentage or yield of saleable cuts as proportion of chilled carcass WT except that broilers fed Snowbird or Snowdrop had larger ($P < 0.05$) thighs than those fed Fabelle and feeding high-quality seed resulted in larger ($P < 0.01$) pectoralis (breast) minor than low-quality beans (Table 7).

Controls fed SBM only were 110 heavier at slaughter, had 72 g heavier chilled carcass WT, and 0.52%-point greater dressing percentage than broilers fed faba bean diets ($P < 0.05$). Controls fed SBM only had 0.19%-point smaller ($P < 0.05$) pectoralis (breast) minor, 0.43%-point smaller ($P < 0.01$) drumsticks, and 1.07%-point heavier ($P < 0.01$) trim than broilers fed faba bean.

DISCUSSION

Nutrient and ANF Content of Faba Bean

Interestingly, for high-quality seed, Fabelle had lower starch and greater NDF content, whereas

Table 5. Effect of feeding diets including three different faba bean cultivars of two quality levels and a wheat-SBM control diet on growth phase and overall trial (day 0 to 40) growth performance of broilers[1]

		Cultivar				Quality			*P*-value			
	Control	Snowbird	Snowdrop	Fabelle	SEM	High	Low	SEM	Cultivar	Quality	C × Q[2]	Faba bean vs. control[3]
BW, g												
d 0	41.44	41.17	41.12	40.91	0.37	41.29	40.84	0.33	0.7813	0.1762	0.8173	0.3152
d 11	314.03	300.59	303.66	299.74	8.36	300.64	302.02	8.03	0.7680	0.7671	0.3358	0.0710
d 24	1262.87	1219.29	1239.22	1249.57	21.51	1229.76	1242.29	20.30	0.2222	0.3837	0.2941	0.1737
d 40	2991.69	2844.36	2892.05	2899.43	31.11	2880.30	2876.92	25.55	0.3968	0.9246	0.2098	0.0117
ADG, g/d												
Starter[3]	23.55	22.63	22.67	22.78	0.53	22.51	22.88	0.49	0.9601	0.3890	0.2768	0.1334
Grower[4]	72.99	70.19[a]	71.73[a,b]	72.79[b]	1.03	71.13	72.01	0.94	0.0491	0.3003	0.1360	0.1954
Finisher[5]	111.16	103.55	105.36	105.92	1.72	104.88	105.01	1.40	0.6000	0.9484	0.6599	0.0108
Overall	72.86	68.98	70.40	71.05	0.94	69.78	70.51	0.78	0.2691	0.4947	0.3651	0.0316
ADFI, g/d												
Starter	27.11	26.94	27.21	27.32	0.43	27.13	27.18	0.37	0.7636	0.9020	0.2095	0.8816
Grower	97.49	95.85	96.72	97.09	1.56	97.32	95.79	1.45	0.6498	0.1774	0.0536	0.5385
Finisher	190.02	188.97	189.89	188.20	2.55	190.31	187.73	2.12	0.8878	0.3672	0.0192	0.7835
Overall	111.79	111.06	112.21	111.84	1.39	112.15	111.26	1.16	0.8247	0.5672	0.0151	0.9364
G:F, g/g												
Starter	0.869	0.839	0.833	0.829	0.010	0.830	0.838	0.009	0.6694	0.3746	0.9753	0.0046
Grower	0.749	0.733[a]	0.742[a,b]	0.750[b]	0.006	0.731	0.752	0.005	0.0477	0.0004	0.2478	0.3198
Finisher	0.586	0.548	0.555	0.563	0.006	0.551	0.560	0.005	0.2134	0.1890	0.0950	0.0010
Overall	0.652	0.621	0.628	0.635	0.004	0.622	0.634	0.003	0.0694	0.0168	0.0300	0.0004

[a–b] Means within a row without a common superscript differ ($P < 0.050$).

[1]Least-square means based on nine pens of 11 or 12 broilers each per faba bean cultivar ×quality level.

[2]*P*-value for the interaction between faba bean cultivar and quality level.

[3]*P*-value for the contrast comparing feeding all six faba bean diets to control.

[3]d 0 to 11.

[4]d 12 to 24.

[5]d 25 to 40.

Table 6. Interaction between faba bean cultivar and quality level on growth performance of broilers[1]

	Snowbird High	Snowdrop High	Fabelle High	Snowbird Low	Snowdrop Low	Fabelle Low	SEM
ADFI, g/d							
Finisher	193.60[a,b]	185.29[a,b]	192.04[a,b]	184.33[b]	194.50[a]	184.37[b]	3.53
Overall	113.33[a,b]	109.34[b]	113.78[a,b]	108.79[b]	115.09[a]	109.90[a,b]	1.93
G:F							
Overall	0.611[c]	0.631[a,b]	0.624[b,c]	0.632[a,b]	0.624[b,c]	0.646[a]	0.006

[a–c]Means within a row without a common superscript differ ($P < 0.050$).

[1]Least-square means based on nine pens of 11 or 12 broilers each per faba bean cultivar × quality level.

for low-quality beans, Fabelle had greater starch and lower NDF content than Snowbird and Snowdrop. The NDF content in faba bean cultivars was similar to that reported in a recent study (10.9–12.6%; Ivarsson and Neil, 2018) but lower than in older studies (12.6–26.4%; Duc et al., 1999; Jezierny et al., 2010). Content of condensed tannins in both high- and low-quality Fabelle was similar to that reported by Cho et al. (2019). Content of condensed tannins in Fabelle was within the expected range of 5 to 10 g/kg DM (Duc et al., 1999). Some condensed tannins were measured in low-quality Snowdrop even though this cultivar was a zero-tannin. All three cultivars were planted in bands beside each other, so crosspollination among cultivars cannot be ruled out. However, level was so low that it likely did not play a role affecting broiler growth performance. Vicine and convicine content of faba bean cultivars was within expected range. In conventional cultivars like Snowbird and Snowdrop, vicine and convicine content ranges from 6 to 14 g/kg DM, whereas cultivars with reduced vicine-convicine content like Fabelle averaged 0.6 g/kg DM (Duc et al., 1999). Mayer Labba et al. (2021) recently reported that the vicine content of 15 cultivars grown in Sweden ranged from 0.40 to 7.01 g/kg DM and convicine content ranged from 0.04 to 3.12 g/kg DM. Vicine and convicine contents in the current trial were similar to those reported by Cho et al. (2019) and Smit et al. (2021).

Faba Bean Cultivars

No difference in feed disappearance among faba bean cultivars indicates that condensed tannins and(or) vicine and convicine content, to the extent found in this trial, did not affect palatability of the diets. In the grower phase, when faba bean inclusion was 30%, both weight gain and feed efficiency were greater for Fabelle than Snowbird. As explained by Cho et al. (2019), Fabelle may have greater energy digestibility because of low vicine and convicine content. Vilariño et al. (2009) showed that AME_n was reduced by 0.5 MJ/kg DM for faba bean averaging 9.9 versus 1.3 g/kg tannin content and by 0.35 MJ/kg DM for faba bean averaging 10.1 versus 0.7 g/kg vicine and convicine content; the negative effects of both antinutritional factors on energy were additive. These authors also showed that the apparent ileal digestibility (**AID**) of crude protein was reduced from 86% to 75% for faba bean with 1.3 versus 9.9 g/kg tannin content and found no interaction with vicine and convicine content. On the other hand, our recent broiler digestibility trial showed no difference in digestibility of GE and CP among Snowbird, Snowdrop and Fabelle. Fabelle did have lower digestibility for most AA than Snowbird and Snowdrop, but Fabelle had greater AA content that offset the lower digestibility and resulted in similar standardized ileal digestible AA content in all three cultivars. It is, therefore, unclear why Fabelle improved weight gain and gain-to-feed ratio in the grower but not in the starter and finisher phases.

Broilers fed Fabelle had lower thigh yield than those fed Snowbird or Snowdrop. This finding is not in agreement with our previous results (Cho et al., 2019) that showed no difference in thigh yield among broilers fed Fabelle, Snowbird and Snowdrop. However, Cho et al. (2019) did find decreased thigh yield for broilers fed Malik, a faba bean cultivar with greater content of both condensed tannins and vicine and convicine compared with Snowbird, Snowdrop, or Fabelle. Thigh yield is more susceptible to small changes in nutrient intake than yield of drumsticks and wings. Cho et al. (2019) also found differences in breast yield; birds fed Snowbird had greater breast (pectoralis major) yield than those fed Snowdrop or Fabelle. Such reported finding is not in agreement with results from the current trial that showed no effect of cultivar on breast yield.

Faba Bean Quality Level

To our knowledge, this is the first research trial reporting the effect of feeding frost damaged faba bean on broiler performance. These

Table 7. Effect of feeding diets including three different faba bean cultivars of two quality levels and a wheat-soybean meal control diet on carcass traits and yield of saleable cuts of broilers[1]

		Cultivar				Quality			*P*-value			
	Control	Snowbird	Snowdrop	Fabelle	SEM	High	Low	SEM	Cultivar	Quality	C × Q[2]	Faba bean vs. control[3]
Antemortem weight, kg	2.86	2.71	2.76	2.77	0.04	2.74	2.76	0.03	0.3370	0.7458	0.3269	0.0150
Carcass weight, kg	2.12	2.03	2.07	2.05	0.03	2.04	2.06	0.03	0.5201	0.5525	0.5328	0.0414
Dressing, %	74.77	74.26	74.12	74.25	0.19	74.14	74.28	0.18	0.5728	0.2427	0.7221	0.0014
Carcass component yield, % of chilled carcass												
Breast major	29.75	29.56	29.59	30.09	0.26	29.75	29.74	0.21	0.2821	0.9628	0.1043	0.9928
Breast minor	5.70	5.90	5.86	5.92	0.06	6.00	5.79	0.05	0.7731	0.0028	0.6255	0.0233
Breast total	35.51	35.46	35.46	36.02	0.27	35.76	35.53	0.22	0.2592	0.4812	0.1804	0.7168
Thighs	14.99	15.51[a]	15.43[a]	14.94[b]	0.18	15.29	15.31	0.16	0.0189	0.9310	0.8665	0.1590
Drumsticks	12.73	13.28	13.18	13.02	0.10	13.18	13.15	0.09	0.2123	0.8125	0.4995	0.0071
Wings	10.04	10.08	10.12	10.11	0.07	10.13	10.08	0.06	0.9511	0.5547	0.0842	0.5416
Trim	26.86	25.55	25.91	25.92	0.23	25.62	25.96	0.19	0.4151	0.1925	0.5623	0.0023

[a–b] Means within a row without a common superscript differ ($P < 0.050$).
[1] Least-square means based on nine pens of 11 or 12 broilers each per faba bean cultivar × quality level.
[2] *P*-value for the interaction between faba bean cultivar and quality level.
[3] *P*-value for the contrast comparing feeding all six faba bean diets to control.

growth performance results confirm our recent broiler digestibility results that showed that planting and harvesting faba bean late versus early to purposely induce frost damage increased gross energy, crude protein, and amino acid digestibility (Smit et al., 2021). Pulse growers generally phase delayed planting due to a wet spring, early frost at harvest time, or a combination of both, and that is accentuated in late maturing cultivars. One would logically expect that feeding low-quality faba bean, which consisted of a considerable proportion of frost-damaged (blackened hull) and immature (soft and green) beans would reduce growth performance. Surprisingly, we found no difference or greater gain-to-feed ratio in grower phase and an interaction for the overall trial but largely in favor of feeding low-quality beans versus high-quality seed. Low-quality faba bean had slightly greater crude fat content and 7% greater gross energy value than high-quality seed, which may have contributed to greater gain-to-feed ratio.

Little research has been conducted feeding frost-damaged grain to monogastric animals. Bell et al. (1985) and Bell and Keith (1986) fed frost-damaged canola seed to growing pigs. They showed improved feed intake and growth rate with increasing frost damage but no effect on feed efficiency. These authors suggested that frost-damaged canola seed was more palatable because of lower glucosinolate content, an antinutritional factor that imparts a bitter taste (Smit et al., 2014). They speculated that frost ruptured cell walls in the seed thereby allowing enzymes to break down glucosinolates and(or) improved digestibility of cell contents. In our frost-damaged faba bean, levels of condensed tannins were not markedly different from parent high-quality seed, but vicine and convicine content was somewhat lower in low versus high-quality faba bean. Improved digestibility could be another reason for improved gain-to-feed ratio. Indeed, we recently reported greater digestibility in broiler chickens for faba bean with high versus low proportion of frost damage and immature beans (Smit et al., 2021). We argued that immature beans may have had a greater proportion of highly digestible mono- and disaccharides (glucose, fructose, and sucrose) and(or) a lower proportion of non-digestible raffinose family oligosaccharides (raffinose, stachyose, and verbascose) than ripe beans (Landry et al., 2016). Hejdysz et al. (2016) showed a negative correlation between AME_n of faba bean and content of oligosaccharides and raffinose suggesting that our low-quality beans may have had greater energy digestibility resulting in better gain-to-feed ratio.

They also reported similar negative correlations with AID of dry matter, starch, crude protein, and amino acids. α-Galactosides accumulate during the final stage of ripening to stabilize cell membranes at desiccation and again when the seed rehydrates during germination (McPhee et al., 2002) but vanish soon after (Guillon and Champ, 2002).

Visually, the tannin-containing bean cultivar Fabelle had a lower proportion of frost-damaged beans than zero-tannin cultivars Snowbird and Snowdrop (Smit et al., 2021). This finding agrees with Henriquez et al. (2018) who reported that tannin-containing cultivars showed lower proportions of blackened hull beans when compared with zero-tannin cultivars after frost exposure. Less frost damage in Fabelle was possibly because of the frost-protective effect of condensed tannins through their activity as a supercooling promoting agent or anti-ice nucleating agent, preventing intracellular ice formation and subsequent damage (Koyama et al., 2014). With different proportion of frost damage observed among our low-quality cultivars, one would expect an interaction effect between cultivar and faba bean quality level on broiler performance. Indeed, that was the case for feed disappearance and gain-to-feed ratio in the finisher phase and overall trial. However, this interaction showed that low-quality Snowdrop stood out, not Fabelle. Broilers fed low-quality Snowdrop had increased feed intake compared with high-quality Snowdrop, whereas quality level did not affect feed disappearance for Snowbird or Fabelle. Moreover, broilers fed low-quality Snowdrop had gain-to-feed ratio no different from high-quality Snowdrop, whereas feeding low-quality Snowbird and Fabelle resulted in better gain-to-feed ratio than high-quality seed. The low-quality Snowdrop had lower starch and greater NDF content than the high-quality Snowdrop, which may have lowered its energy value, which in pigs is known to increase feed intake (Smit et al. 2017, 2018). Despite small differences in quality level among cultivars, this trial demonstrated that low-quality faba bean can be fed to broilers without major concerns. This finding is of practical relevance to pulse growers who would now have a market for frost-damaged and(or) immature faba beans that would be rejected for human food. As well as for poultry producers who might take advantage of buying lower quality faba bean at a discounted price. However, frost-damaged and(or) immature faba bean would not make seed stock because frost damage to the embryo would reduce germination. The results of this trial should not encourage feeding extremely damaged, heated, or rotten beans to poultry as acceptable health and growth performance would not be guaranteed. It would be recommended instead to dilute a batch of frost damaged beans with a batch that shows little or no frost damage.

Faba Bean Diets Versus Control

The results of this trial comparing feeding faba bean diets versus a wheat-soybean meal only control diet to broilers was similar to our previous results (Cho et al. 2019; Kopmels et al., 2020). Overall and growth phase feed disappearance was not different confirming that antinutritional factors in faba bean such as condensed tannins and vicine and convicine, at the levels fed in this study, did not reduce palatability of the diets. Weight gain was reduced in the finisher phase when faba bean inclusion level pushed 45%. Lower weight gain in the finisher phase for broilers fed faba bean diets versus control resulted in lower overall weight gain, lower body weight at the end of the trial, and with that, lower carcass weight. Feeding faba bean instead of a wheat-soybean meal control diet also resulted in lower gain-to-feed ratio in the starter and finisher phases and overall, which agrees with our previous results (Cho et al., 2019; Kopmels et al., 2020). These minor negative effects could be because a slight overestimation of digestibility of amino acids in faba bean in our feed formulation matrix. The results of our digestibility trial were not ready yet (Smit et al., 2021), so faba bean diets were formulated based on amino acid digestibility coefficients obtained from AMINOD at 5.0. Different faba bean cultivars have different amino acid digestibility as shown by Nalle et al. (2010) and Koivunen et al. (2016). Increasing crude fiber content in faba bean diets by growth phase may be the reason why broilers fed faba bean had slightly lower dressing percentage than controls, which is consistent with our previous results (Cho et al., 2019; Kopmels et al., 2020). Bigger drumstick yield in broilers fed faba bean versus controls was also reported by Cho et al. (2019) and Kopmels et al. (2020) and could be because controls achieved greater antemortem weight.

Considering that SBM is a highly processed product (including flaking, dehulling, heating, pressing, hexane-washing, and desolventizing [Wright, 1981]) versus feeding raw faba bean that was merely rolled to reduce particle size, it was not surprising to us to observe somewhat reduced growth performance for broilers fed faba bean versus the soybean meal only control diets.

However, changes in antemortem body weight and carcass weight were small, and broilers fed faba bean had lower carcass trim, greater breast minor and drumstick yield, hence the carcass value of broilers fed faba bean was still high.

In conclusion, the results of this experiment indicate that feeding frost damaged and(or) immature, low-quality faba bean, to the extent observed in this trial, did not negatively affect growth performance or carcass attributes of broiler chickens compared to feeding parent, certified seed quality of these faba bean cultivars (Snowbird, Snowdrop, and Fabelle).

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