PAPER

Buckwheat bran (*Fagopyrum esculentum*) as partial replacement of corn and soybean meal in the laying hen diet

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Abstract

The effect of partial substitution of corn (-20%) and soybean meal (-10%) with buckwheat bran (+30%) (*Fagopyrum esculentum* Moench) in the diet of ISA-Brown hens was investigated in sixteen 74-week old hens, housed in couple wire cages and submitted to a 16 h light:8 h dark photoperiod. The following traits were measured: body weight, egg production, egg mass, egg quality, feed intake, feed conversion, comparative palatability of ingredients and digestibility of diet. χ^2 and non-parametric tests were used for production rate and yolk color score, respectively. ANOVA was used for all other parameters. Comparative choice of buckwheat, corn and soy was checked under different forms in 3 free choice tests. Results show that egg production rate (43.3% *vs* 50.5%; $P<0.05$) and feed intake (78.3±0.68 eggs/hen d *vs* 87.8±0.68 eggs/hen d; $P<0.05$) increased with the partial introduction of buckwheat bran in the diet. There was no difference in feed conversion between treatments. Nutrient balance confirmed that AMEn of diet was deeply lowered by the buckwheat bran use (6.5 MJ/kg *vs* 10.1 MJ/kg), due to the high fibre content of buckwheat bran (263 g/kg). Maize was always the most preferred ingredient, buckwheat bran was consumed more than expected in absence of any preference, and soybean was the food least chosen. Buckwheat bran can be used as an ingredient feed for low-producing laying hens; it induces a feed-intake increase, partially balanced by improved egg-production rates and a tendency to better albumen Haugh units.

Introduction

Common buckwheat (*Fagopyrum esculentum* Moench, *Polygonaceae*) is an under-used grain crop. Its seeds are produced in many countries (Table 1) and the estimated world production is 1,787,547 tons (FAO, 2011). Buckwheat is particularly popular in Japan, Russia, and Central and Eastern Europe (Steadman *et al*., 2001). After harvesting, the hull (pericarp) is removed from buckwheat seed by impact milling (yield approximately 17-20%) then the resulting groat (or the intact achene) is roller-milled and the product sifted to remove the bran (fragmented hull, yield approximately 10-24%). Light flour (yield approximately 55-70%) is used in many forms in foods for human consumption, such as buckwheat pancakes, breads, soba, pasta, etc. (Bonafaccia *et al*., 2003; Steadman *et al*., 2001).

In the past, buckwheat groat was commonly used in feed for laying hens since it is a valid nutritional ingredient, rich in essential amino acids (Steadman *et al*., 2001). Buckwheat is now an emerging crop for human consumption. It is arousing much interest among celiac individuals because of its lack of gluten content and the presence of prophylactic components, such as flavonoids and flavones, phytosterols, fagopyrins and thiamin-binding proteins (Alvarez-Jubetea *et al*., 2010; Krkošková and Mrázová, 2004). Buckwheat bran is a waste matter (derived by the gluten free food industry) not commonly used for human consumption. Since the employment of by-products or *green feeds* minimizes the impact of poultry in terms of land requirements for poultry feeding (they are not used in competition with *classical* foods) (Çiftci *et al*., 2003), the aim of this study was to evaluate the effects of the partial substitution of corn and soybean meal with buckwheat bran in the diet of laying hens and evaluate its comparative palatability.

Materials and methods

Diet

Experimental diet was prepared by incorporating buckwheat bran at a level of 30% in a corn-soy based laying-hen diet as partial substitution of 20% of corn and 10% of soybean. The ingredients and chemical composition of the control and experimental diets are shown in Table 2.

Sixteen ISA-Brown hens, 74 weeks of age, were housed in couple wire cages (36.5 cm × 23.0 cm × 40.0 cm h) and kept with a light:dark cycle of 16 h light:8 h dark. Feed and water were available *ad libitum.*

The effect of the partial substitution of corn and soybean with buckwheat bran was tested over two experimental periods. In the first period, each dietary treatment was randomly assigned to 8 hens (two hens per cage) and, after an adaptation period (14 days), the performance was monitored for 14 days. The treatments were then shifted between hens, and after a second adaptation period, the performance was monitored for 14 days.

Animals and experimental plan

Hen-day egg production, egg shell, albumen and yolk weight, and commercial value of eggs in terms of shell thickness, Haugh units and yolk color were measured daily. Feed intake (g/hen d) was recorded weekly. Animals were weighed at the beginning of the trial and every two weeks. Faecal and feed samples were also collected from every cage at the end of each experimental period.

Eggs were collected in the morning and immediately weighed individually to the nearest 0.1 g. After weighing, the eggs were allowed to cool to room temperature for a 6-h equilibration period. After this, each egg was broken out on a Petri-plate to evaluate the following parameters (Stadelman and Cotterill,

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1995):
- compositional weights, eggshell and yolk were directly weighed to the nearest 0.1 g;
- albumen weight was calculated per difference;
- egg shell thickness was determined by measuring three random points in the three main eggshell parts (acute pole, equator, obtuse pole) using an Ames micrometer (S-6428, BC Ames, Melrose, MA, USA);
- albumen quality was measured by Haugh unit (Eisen *et al*., 1962);
- yolk color was measured by the Roche yolk color fan (Vuilleumier, 1969).

Faecal and feed samples were collected from each cage for one week, pooled in two samples for each experimental period, and analyzed according to the Association of Official Analytical Chemists (1990).

The apparent digestibility (AD) at excreta level of energy and nutrients was then calculated, using acid-insoluble ash (AIA) as the indigestible natural marker (Sales and Janssen, 2003b), as shown below:

$$AD\ (\%) = \frac{[(\text{Energy or Nutrient})/AIA]d - [(\text{Energy or Nutrient})/AIA]e}{[(\text{Energy or Nutrient})/AIA]d} \times 100.$$

where:
[(Energy or Nutrient)/AIA]d = ratio of Energy or Nutrient to acid-insoluble ash in the diet,
[(Energy or Nutrient)/AIA]e = ratio of Energy or Nutrient to acid-insoluble ash in the excreta. The mean value of 3 samples of approximately 1 g each of dry matter was used to determine AIA in the samples.

Food choice test

The food choice trial lasted five days with 14 ISA-Brown hens of 82 weeks of age. Hens kept in the same wire cages of the performance test were given free and continuous access to maize, soybean and buckwheat alone in a different sub-space of a special feeder. Hens were given *ad libitum* access to water and a calcium source. The position of each test food was randomly changed every day (Emmans, 1991). In addition to mash (particles <1 mm) (Ensor *et al*., 1969) two other different particle sizes were tested: whole grains and cracked grains (2 mm = < particles <4 mm).

Buckwheat bran was employed only in the mash-test; whole buckwheat was employed in the whole and cracked grain tests; whole cooked soybean was used instead of soybean meal de-hulled, solvent in the grain test. The groups of animals counted 4, 4, and 6 hens in the three tests, respectively. The preference for each food in each test was calculated as follows:

$$\text{Preference} = \frac{FIi - FG}{FG}$$

where:
FIi = feed intake observed for food *i* per hen and per day.
FG = expected animal food consumption; in absence of preference; when given three foods, in absence of any preference hens should eat equal amounts of each and hence, the composition of the diet should have been (0.33M + 0.33S + 0.33B) where M, S and B are maize, soybean and buckwheat, respectively.

Statistical analysis

Results are presented as means ± standard error. The following were used to analyze data from performance test:
- χ^2 distribution for egg production rate;
  non parametric Wilcoxon's signed-rank for yolk color score;
- every other parameter by ANOVA (SAS Institute, 2002); variance of the error was

Table 1. Buckwheat production in the world (tonnes).

EUROPE	991,291
Belarus	19,430
Croatia	300
Czech Republic	2041
Estonia	91
France	114,500
Hungary	2350
Latvia	4800
Lithuania	14,700
Moldova	300
Poland	81,226
Russian Federation	564,040
Slovakia	84
Slovenia	944
Ukraine	188,600
AMERICA	142,196
Brazil	53,487
Canada	2362
United States of America	86,347
AFRICA	300
South Africa	300
ASIA	653,846
Bhutan	3898
China	570,000
Georgia	100
Japan	15,300
Kazakhstan	62,000
Korea	2500
Republic of Kyrgyzstan	48
Ukraine	188,600
OCEANIA	0
World total = 1,787,547	

Source: Fao, 2011.

Table 2. Dietary composition and calculated dietary nutrient content of diets fed to laying hens (air-dry basis).

	Control		Buckwheat
Ingredients			
Maize, g kg^{-1}	595.2		395.2
Soybean meal de-hulled, solvent, g kg^{-1}	246.8		146.8
Buckwheat bran, g kg^{-1}	-		300.0
$CaCO_3$, 38% Ca, g kg^{-1}		52.3	
Wheat, shorts, g kg^{-1}		30.1	
Oats, g kg^{-1}		14.0	
Wheat germ meal, g kg^{-1}		14.0	
Molasses beet, g kg^{-1}		14.0	
$CaHPO_4$, 24% Ca 17% P, g kg^{-1}		10.5	
Vegetable oil, g kg^{-1}		9.8	
Alfalfa meal, dehydrated, g kg^{-1}		7.0	
NaCl, g kg^{-1}		2.1	
$NaHCO_3$, g kg^{-1}		0.6	
Premix°, g kg^{-1}		3.6	
Calculated dietary nutrient content			
Metabolizable energy, MJ kg^{-1}	12.0		10.7
Crude protein, g kg^{-1}	179		179
Lysine#, g kg^{-1}	9.5		9.7
Methionine#, g kg^{-1}	3.0		2.8
Methionine + cystine#, g kg^{-1}	5.7		6.3
Crude fibre, g kg^{-1}	29.8		100.1

°Concentrate mixture supplied per kilogram of diet: vitamin A, 10,000 U; vitamin D_3, 2000 U; vitamin E, 25 mg; vitamin K_3, 2 mg; vitamin B_1, 2 mg; vitamin B_2, 5 mg; vitamin B6, 3 mg; vitamin B_{12}, 15 mg; calcium-D-pantothenate, 10 mg; nicotinamide, 30 mg; folic acid, 1 mg; biotin, 100 mg; choline chloride, 250; mg; manganese, 40 mg; zinc, 50 mg; iron, 60 mg; copper, 10 mg; cobalt, 0.3 mg; iodine, 0.5 mg; selenium, 0.2 mg. #The AA composition of ingredients was taken by Dale and Batal (2006) except for buckwheat bran that was taken by Bonafaccia *et al.* (2003).

calculated within the hens fed the same diet in the same period.

Data from food choice were analyzed by ANOVA checking the differences between observed and expected food consumption.

Results and discussion

Performance test

Results of the performance trial are summarized in Table 3. The partial replacement of maize and soybean with buckwheat bran had a significant effect on the increase in feed intake. The increase in feed intake related to the partial replacement of maize and soybean with buckwheat bran was due to the increase of fibre content of the diet and the consequent reduction in feed concentration, in general agreement with observations of Van Krimpena *et al*. (2007). There was a positive influence on laying performance ($P<0.05$) by the experimental diet over the total experimental period (54 to 62 weeks). The increase in hen performance was related to the increase of energy intake, probably due also to the greater palatability of diet containing buckwheat bran. In the actual study with low productive laying hens, performance significantly improved with the use of a feed with a reduced energy concentration, in contrast with the observations reported by Vargas and Naber (1984) who reported that egg production, egg weight and body weight of hens usually decrease or are not significantly improved by a reduction in feed concentration. This was probably due to the fact that we used old and low-productive laying hens which are able to increase their intake and consequently utilize diluted diets better, while high productive hens in the first period of laying need concentrated diets to reach their maximum productivity and, at the same time, to finish growing (Morris, 2004). The hens fed buckwheat bran with at least up to 30% dietary inclusion, performed equally or better to the maize-soy diet (control), similar to observations in broiler chickens by Gupta *et al*. (2002) who used whole buckwheat. The increased feed intake also resulted in a slight but significant body weight gain (+49 g). There was no significant improvement in egg mass production, even if the laying rate had been positively influenced and the egg weight was not reduced. The egg weight, in fact, was only slightly but not significantly positively influenced by the buckwheat bran; its variability affected the parameters which, for this reason, did not reach the minimum statistical difference between treatments. Quantitative and qualitative traits of the eggs are summarized in Table 4. No egg trait was significantly affected by the diet type even if there was no worsening of the average values in the eggs laid by the hens fed the experimental diet, probably due either to the reduced number of egg measured, or to the high variability in the measured parameters. The AMEn in the experimental diet was lower than in the control diet (10.1±1.07, *vs* 6.5±1.34; $MJxkg^{-1}$± standard deviation) so that the introduction of buckwheat bran in the maize-soy based diet resulted in a gross reduction of the hen AMEn of -0.12 MJ for each kg of buckwheat bran inserted in the diet as substitute of two-thirds maize and one-third soybean (Table 2). The high variability observed in the AMEn, similar to that observed by Sales and Jensen (2003a) without supplementation of acid-insoluble ashes, can be explained by the analytical errors related to the natural content of acid-insoluble ashes in our diets which was too low: 9.5 g/kg and 15.5 g/kg, in the control and the experimental diet, respectively (Sales and Janssen, 2003b).

Food choice test

The comparative free food choice of maize soybean and buckwheat under different particle sizes (whole grains, crumbles and mash) are shown in Figure 1.

Table 3. The effect of buckwheat on performance of laying hens from 54 to 62 weeks of age (mean ± standard error).

	Control hens, n. 8		Buckwheat hens, n. 8	
Feed intake, g/hen d	78.3±0.68[a]		87.8±0.68[b]	
Egg production rate, %	43.3[a]		50.5[b]	
Body weight gain, g	-19±22.5[a]		49±20.5[b]	
Egg mass, egg/hen d	58.4±0.72	ns	58.8±0.69	ns
Feed conversion, g feed/g egg	3.0±0.42	ns	3.4±0.42	ns

[a,b]Means with different letters differ ($P<0.05$); ns, not significant.

Table 4. The effect of buckwheat on egg traits (mean ± standard error).

	Control Total eggs, n. 119		Buckwheat Total eggs, n. 104	
Egg weight, g	58.6±0.70	ns	59.3±0.66	ns
Albumen weight, g	37.7±0.59	ns	38.3±0.54	ns
Albumen quality, Haugh unit	89±1.2	ns	92±1.1	ns
Yolk weight, g	14.8±0.20	ns	15.1±0.19	ns
Yolk color, Roche score	12.5±0.10	ns	12.2±0.09	ns
Shell weight, g	6.3±0.12	ns	6.5±0.11	ns
Thickness, 0.01 mm	385±7.1	ns	370±6.3	ns

ns, not significant.

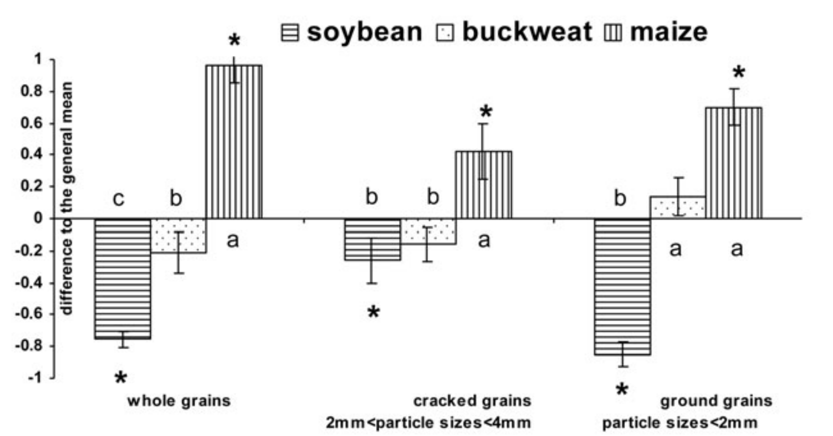

Figure 1. Food choice preference of laying hen to the three component food options (with free and continuous access to Ca-grit and water); a,b,c, different letters show significant differences between component choices; *significantly greater or lower consumption than expected. In whole and cracked grain tests, buckwheat was used instead of buckwheat bran, and in whole grain tests whole cooked soybean was used instead of soybean meal de-hulled, solvent.

Maize was always the most preferred food under every form. This is consistent with choice feeding trial or *free-choice feeding* (Henuk and Dingle, 2002). Buckwheat bran was preferred to soybean in the free-choice feeding test (with mashes) so that when buckwheat partially replaces soybean as protein source in a diet, the palatability of the diet containing buckwheat most likely improves.

For this reason, the partial substitution of maize and soybean by buckwheat did not determine the expected reductions in body weight and production observed by other authors following a feed dilution in the experimental diet (Van Krimpena *et al*., 2007).

Finally, it is interesting to note that in the test with whole grains, despite the color (black) and form (not round) of buckwheat, which are not usually preferred by galliforms, buckwheat was, however, significantly preferred to soy (yellowish color and rounded form).

Conclusions

In the present study, hens fed buckwheat bran performed equally or better than those fed maize or soy. As far as quality eggs traits are concerned, there was no worsening of average values in the group of hens fed the experimental diet. It is interesting to note that soybean was always the food chosen least and free consumption of buckwheat bran (tested with particle sizes <2 mm) was greater than expected in the absence of any preference, and there was no difference in this to maize consumption. In conclusion, we can assume that buckwheat bran can be profitably used to feed laying hens, at least the old or low productive hens, usually employed in the free range or organic systems.

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