Broiler Chick Response to Feeding Heat-Treated Ground Full-Fat Raw Soybeans

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ABSTRACT

Two separate experiments were conducted. In each experiment 440 one day-old commercial broiler chicks were fed starter diets formulated to be isonitrogenous and isocaloric, and containing either commercially processed soybean meal or ground full-fat raw soybeans heated at 100 C and 121 C for 30 and 60 min. The chicks were separated by sexes and reared in battery cages, ten per group. Weekly body weights and feed consumption were obtained on each treatment group. Body weight and feed utilization were significantly reduced when the ground full-fat raw soybeans were used in the starter diet. Autoclaved cooking temperatures of 100 C and a cooking time of 60 min appeared to be the best combination used for cooking the ground full-fat raw soybeans. The response of broiler chicks to feeding ground full-fat raw soybeans appears to be age related. The chicks overcame much of the body weight depression after 3 weeks of age.

KEY WORDS: body weight, feed utilization, cooking temperatures, cooking duration

The use of ground, full-fat soybeans in poultry rations as a source of protein and energy has been investigated by several researchers. Wood et al. (1971), White et al. (1967), Hull et al. (1968), and Smith and Scott (1965) found that chicks receiving diets containing ground raw soybeans had significantly lower body weight gain throughout a 6-week growing period, when compared to birds fed cooked soybean meal.

The nutritive quality of soybeans can be increased by heating. McNaughton and Reece (1980) stated that both moisture and cooking time affect trypsin inhibitor content and broiler growth. Trypsin inhibitor is regarded by many to be the most important proteolytic inhibitor in the poultry diet. Borchers et al. (1984) also found that cooking time affects trypsin inhibitor activity. Autoclaving at 1.02 atmospheres pressure for 4, 10, 15, and 30 min. resulted in 82, 39, 15, and 0% of the original

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trypsin inhibitor activity, respectively. Similarly, Carew et al. (1961) and Carew and Nesheim (1962) evaluated heat treatment time (0, 10, 30 min.) and pelleting on trypsin activity and observed no improvement in the quality of soybean meal. High cooking temperatures reduce the nutritive value of some of the critical amino acids, particularly arginine and methionine.

Little definitive information is available on the relationship between cooking time and temperature on the nutritive quality of raw soybean utilized as a feed ingredient for growing broilers. In addition, evidence for an age-related factor associated with feeding raw soybean is controversial. Alumot and Nitsan (1961) and Wood et al. (1971) have noted an age-dependent function. Salmon and McGinnis (1968) did not support the age-dependent factor observed by Alumot and Nitsan (1961).

Locally grown raw soybeans, properly processed, have a place in the formulation of diets for commercial broilers and other poultry. Their use in poultry diets can be cost-effective by eliminating some of the various steps in the processing of the meal and the extraction of the oil. In addition, it can reduce transportation and some storage costs of the oil. Animal fat and plant oils are added to poultry diets to increase energy requirements. Soybeans are high in protein and oil. Modern poultry companies in the U.S. continue to quest for information on the full use of soybeans, because of the economic potential. Hence, a major objective of the study was to measure the relationship between cooking temperature and cooking time on the nutritive value of ground full-fat raw soybean when used in broiler diets. The second objective was to investigate the age-dependent factor in feeding full-fat raw soybean meal to finishing broiler chickens.

MATERIALS AND METHODS

Two experiments, both factorially designed, compared the effects of different cooking temperatures and cooking durations on the feeding value of ground full-fat soybeans in broiler chick diets. Both experiments utilized Hubbard X Hubbard commercial broiler crosses. The diets were computer formulated to contain 21.58% crude protein (CP) and 3212 kcal of metabolizable energy (ME) per kg of feed (Table 1). All other nutrient requirements were formulated to meet the National Research Council (NRC, 1984) standards. Water was available *ad libitum*. The photoperiod was 24 hours of continuous lighting. The duration of each experiment was 6 weeks.

Data were collected weekly, and the analyses of data were based on analysis of variance procedures outlined in Snedecor and Cochran (1967). Duncan's multiple range test was applied to separate the treatment means (Duncan, 1955). Parameters measured were body weight and feed conversion.

The ground full-fat soybeans used in both experiments were heat-treated in an autoclave at 1.02 atmospheres pressure before incorporation into the diets.

Experiment 1

Two hundred day-old broiler chicks were separated by sex and assigned equally to 5 dietary treatments in a 5 X 2 factorially designed experiment. Each dietary treatment was assigned to two replicate groups of ten males and ten females each. Diet 1 contained commercial solvent extracted soybean meal; Diet 2 consisted of

Table 1. Composition of the broiler diets in Experiment 1.

Ingredients	Diets[1]				
	1	2	3	4	5
	%				
Corn, yellow	50.37	50.37	50.37	50.37	--
Soybean meal (44%)	37.47	37.47	--	--	--
Soybean meal (raw) (38%)	--	--	47.20	47.20	25.69
Cottonseed meal (41%)	--	--	--	--	5.00
Meat & bone meal (50%)	--	--	--	--	--
Calcium carbonate	1.40	1.40	1.27	1.27	1.66
Mono-Cal-Phos	1.76	1.76	2.15	2.15	.50
Salt (NaCl)	.50	.50	.50	.50	.50
Broiler vitamin premix	.50	.50	.50	.50	.50
DL-Methionine (98%)	.19	.19	.18	.18	.25
Lysine	--	--	--	--	.20
Coban	.05	.05	.05	.05	.05
Blended fat	7.76	7.76	--	--	7.00
Analysis:					
ME (kcal/kg)	3212	3212	3212	3212	3212
Crude protein (%)	21.58	21.58	21.58	21.58	21.58

[1]Legend (treatment of soybean meals)
(1) unheated commercial soybean meal
(2) heated commercial soybean meal at 121 C 30 min.
(3) ground raw soybean meal heated at 100 C for 30 min.
(4) ground raw soybean meal heated at 121 C for 30 min.
(5) non-soybean meal diet.
Vitamin concentrate provided the following micronutrients per kilogram of diet: vitamin A, 8,800 IU; vitamin D3, 2,200 IU; vitamin E, 2.75 IU; menadione, 2.2mg; riboflavin 4.4 mg; D-pantothenic acid,12.1 mg choline chloride, 500 mg; niacin, 22 mg; vitamin B12, .013mg; biotin, .055 mg; thiamin, 1.1 mg.

Table 2. Composition of the broiler diets in Experiment 2.

Ingredients	Diets[1]					
	1	2	3	4	5	6
	%					
Corn, yellow	50.35	50.35	47.96	47.96	47.96	47.96
Soybean meal (44%)	37.47	37.47	--	--	--	--
Soybean meal (raw) (38%)	--	--	47.38	47.38	47.38	47.38
Calcium carbonate	1.40	1.40	1.33	1.33	1.33	1.33
Mono-Cal-Phos	1.76	1.76	2.16	2.16	2.16	2.16
Salt (NaCl)	.42	.42	.42	.42	.42	.42
Broiler vitamin premix	.50	.50	.50	.50	.50	.05
DL-Methionine (98%)	.20	.20	.20	.20	.20	.20
Coban	.05	.05	.05	.05	.05	.05
Vegetable fat	7.85	7.85	--	--	--	--
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0
Analysis:						
ME (kcal/kg)	3212	3212	3212	3212	3212	3212
Crude protein (%)	21.58	21.58	21.58	21.58	21.58	21.58

[1]Legend (treatment of soybean meals)
(1) unheated commercial soybean meal
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commercial solvent extracted soybean meal heated for 30 min at 121 C in an autoclave; Diet 3 contained ground, full-fat raw soybean meal heated for 30 min at 121 C. The soybean meal in Diet 5 was replaced with cottonseed meal and meat and bone meal to serve as a negative control (Table 1).

Experiment 2

In Experiment 1, the effect of cooking time of the ground full-fat raw soybeans became a factor of concern in interpreting the body weight data. Consequently, cooking duration, as well as cooking temperature, were incorporated into the second experiment.

Experiment 2 was 6 X 2 factorially designed, utilizing six diets with soybean serving as the main protein source to all diets.

Two hundred and forty day-old broiler chicks, equally divided by sexes, were randomly assigned to 24 battery brooder cages, with 10 chicks of one sex per cage. Diets used in Experiment 2 are show in Table 2. Diet 1 served as the control and contained commercial solvent extracted soybean meal (44% protein). Diet 2 contained commercial solvent extracted soybean meal autoclaved at 121 C for 30 min. Diets 3, 4, 5, and 6 contained ground full-fat soybeans heated as follows: diet 3 consisted of ground full-fat soybeans heated for 30 min at 100 C, diet 4 contained ground full-fat soybeans heated for 60 min at 100 C, Diet 5 contained ground full-fat raw soybeans heated for 30 min at 121 C, and Diet 6 was autoclaved for 60 min at 121 C. Feed samples from Experiment 2 were collected from each diet and analyzed for urease activity.

RESULTS

Experiment 1

Chicks fed Diets 3, 4, and 5 weighed significantly ($P < .05$) less than the control (Diet 1), even as early as the first week of growth (Table 3). The chicks receiving Diets 3 and 4 maintained considerably lower body weights through 3 and 6 weeks of age, than those on Diets 1 and 2. (Table 3). When mean body weights of chicks on Diets 3 and 4 were compared on percentage basis with mean body weight of chicks on Diet 1, the birds became adjusted to the ground full-fat raw soybean as with age. Also, the higher cooking temperature used to process the soybeans for Diet 4 (121 C) resulted in an 89 g advantage in body weight over the chicks fed Diet 3, where the soybean was cooked at 100 C. The lowest body weight was obtained with Diet 5 in which soybean meal was replaced with cottonseed and meat and bone meal. Body weight at 6 weeks of age was depressed to an average of 1176 g, as compared with 1718 g for the control, possibly because of gossypol toxicity.

Feed conversion was significantly affected ($P < .05$) by diets at 3 and 6 weeks of age (Table 3). However, chicks fed the heat-treated ground full-fat raw soybean (Diets 3 and 4) had depressed feed conversion during the early stage of growth. There were no statistically significant sex by diet interactions; hence, treatment least squares means of the males or females were combined giving equal weight to sexes.

Table 3. The effect of diets on body weight and feed conversion (g feed per g body weight) at 3 and 6 weeks of age in broilers combining sexes (Experiment 1).

Diets	Body weights			Feed conversion	
	1-wk	3-wks	6-wks	3-wks	6-wks
	---------- g ----------				
1	169 a*	678 a	1673 a	1.153 a	1.499 a
2	170 a	692 a	1695 a	1.134 a	1.543 a
3	116 b	537 b	1363 b	1.213 b	1.736 b
4	113 b	562 b	1452 b	1.189 ab	1.712 b
5	121 b	438 c	1176 c	1.305 b	1.564 a

*Means within columns with the same letter are not significantly different ($P < .05$).
Diet Legend:

1. Unheated commercial soybean meal.
2. Heated commercial soybean meal at 121 C for 30 min.
3. Ground full-fat raw soybeans heated at 100 C for 30 min.
4. Ground full-fat raw soybeans heated at 121 C for 30 min.
5. Non-soybean meal diet.

Table 4. The effect of diets on body weight and feed conversion (g feed per g body weight) at 3 and 6 weeks of age in broilers combining sexes (Experiment 2).

Diets	Body weights			Feed conversion	
	1-wk	3-wks	6-wks	3-wks	6-wks
	---------- g ----------				
1	138 a*	598 a	1755 a	1.385 c	1.575 c
2	136 a	645 a	1637 a	1.453 c	1.683 b
3	87 c	348 c	1155 b	1.708 a	1.835 a
4	106 b	533 b	1662 a	1.590 c	1.738 a
5	84 c	320 c	974 b	1.723 a	1.948 a
6	115 b	531 b	1596 a	1.620 b	1.759 b

*Means within columns with the same letter are not significantly different ($P < .05$).
Diet Legend:

1. Unheated commercial soybean meal.
2. Heated commercial soybean meal at 121 C for 30 min.
3. Ground full-fat raw soybeans heated at 100 C for 30 min.
4. Ground full-fat raw soybeans heated at 100 C for 60 min.
5. Ground full-fat raw soybeans heated at 121 C for 30 min.
6. Ground full-fat raw soybeans heated at 121 C for 60 min.

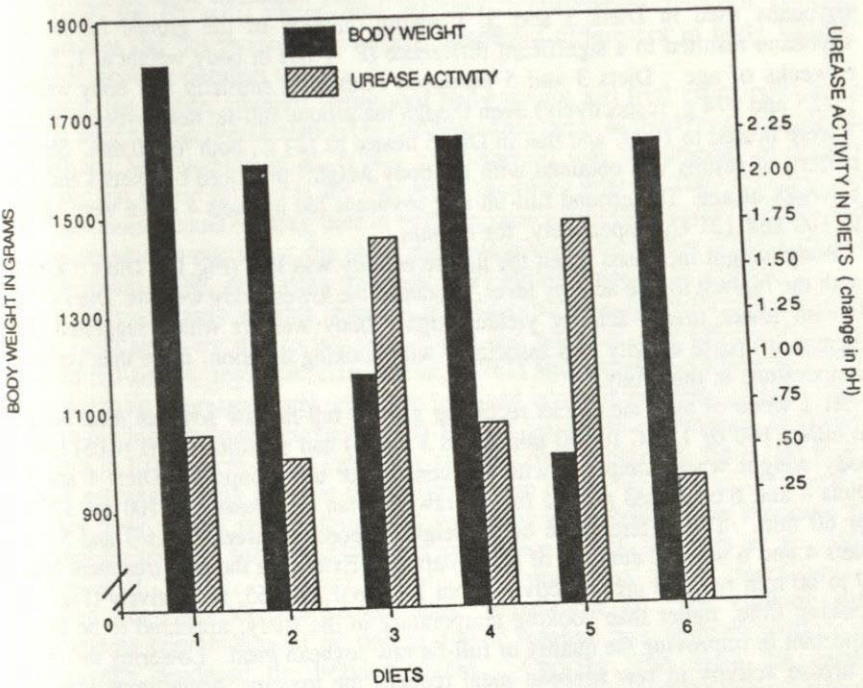

Figure 1. The influence of dietary urease activity on 6-week body weight of broilers combining sexes in Experiment 2.

Diet Legend:

1. Unheated commercial soybean meal.
2. Heated commercial soybean meal at 121 C for 30 min.
3. Ground full-fat raw soybeans heated at 100 C for 30 min.
4. Ground full-fat raw soybeans heated at 100 C for 60 min.
5. Ground full-fat raw soybeans heated at 121 C for 30 min.
6. Ground full-fat raw soybeans heated at 121 C for 60 min.

Experiment 2

Significant dietary treatment effects ($P < .05$) on body weight were noted throughout the 6 weeks of Experiment 2 (Table 4). Body weights of birds fed Diet 1 (the control) and Diet 2 were significantly ($P < .05$) greater at 1 and 3 weeks of age than those for the other four diets. Diets 3, 4, 5, and 6 contained variously treated ground full-fat raw soybean meal. Among the groups fed ground full-fat raw soybeans, body weights of those fed Diets 4 and 6 were significantly ($P < .05$) heavier than those fed Diets 3 and 5 at both 3 and 6 weeks of age. The soybeans used in Diets 4 and 6 were heated for 60 min, compared with 30 min for the soybeans used in Diets 3 and 5. Cooking duration of the ground full-fat raw soybeans resulted in a significant difference ($P < .05$) in body weight at 1, 3, and 6 weeks of age. Diets 3 and 5 produced birds with similarly low body weights (1155 and 974 g, respectively) even though the ground full-fat raw soybeans in Diet 3 were heated to 100 C and that in Diet 5 heated to 121 C, both for 30 min. Similar pattern of results was obtained with the body weights produced by Diets 4 and 6 at 6 weeks of age. The ground full-fat raw soybeans fed in Diets 4 and 6 were heated to 100 and 121 C, respectively, for 60 min.

Body weight increased when the urease activity was low (Fig.1). Diets 3 and 5, with the highest urease activity level, produced the lowest body weights. Diets 4 and 6 with lower urease activity yielded higher body weights which suggested that increased urease activity was associated with cooking duration, more than cooking temperature in this study.

At 1 week of age, the chicks receiving ground full-fat raw soybean meal heated to either 100 or 121 C for 30 min (diets 3 and 5) had significantly ($P = .05$) lower body weight when compared with the controls or the groups fed Diets 4 and 6. Diets 4 and 6 contained ground full-fat raw soybean meal heated at 100 and 121 C for 60 min. The difference in body weight response between Diets 3 and 5 and Diets 4 and 6 was the duration of heat treatment. Extending the heat treatment from 30 to 60 min reduced urease activity from 1.75 to 0.35-0.65, respectively (Fig. 1). Cooking time, rather than cooking temperature in the study, appeared to be more important in improving the quality of full-fat raw soybean meal. Lowering the level of urease activity in raw soybean meal reduces the toxicity, hence improving its nutritive value for broiler chickens.

At 6 weeks of age, the broilers receiving ground full-fat raw soybean meal heated to 100 and 121 C for 60 min (Diets 4 and 6, respectively) were similar in body weight to the controls (Diets 1 and 2) (Table 4). The broilers fed ground full-fat raw soybeans heated for only 30 min weighed significantly ($P < .05$) less than the controls or the birds fed the full-fat soybean meal cooked for 60 min.

The poorest feed conversion at 6 weeks of age was obtained from broilers fed full-fat raw soybean meal cooked at 100 C for either 30 or 60 min, and the treatment group receiving meal cooked at 121 C for 60 min (Table 4). Birds in the positive control group (Diet 1) had the best feed utilization (1.575 feed conversion).

The difference in mean body weight between Experiment 1 and Experiment 2 was seasonally related. Experiment 2 was done in the fall.

DISCUSSION

It is well documented that ground full-fat, raw soybeans depress growth. White et al. (1967), Salmon and McGinnis (1968), Hull et al. (1968), and Wood et al. (1971) have shown that birds receiving ground full-fat raw soybean diets were significantly smaller in body weight to 6 weeks of age than birds fed heat-treated full-fat soybean meal. In the current study, ground full-fat raw soybeans also depressed body weight and feed efficiency to 6 weeks of age. It appeared that the two cooking temperatures used (100 and 121 C) were adequate, provided the ground raw soybeans were autoclaved for 60 min, rather than 30 min. Differences between cooking temperatures did not produce statistically significant differences in body weight; however, cooking duration did.

Urease, the trypsin inhibitor, influenced body weight and feed efficiency. Body weight improved as urease activity in the diets decreased. McNaughton and Reece (1980) and McNaughton et al. (1981) demonstrated that the amount of trypsin inhibitor and urease activity in the diet relate to chicks growth. They also showed that both moisture and cooking time of soybean meal affect the trypsin inhibitor and urease activity. In our study, the entire diet was assayed for urease activity, rather than soybeans alone, supporting the findings of McNaughton et al. (1981).

The depressed body weights observed in chicks fed ground full-fat raw soybeans at an early age were due to low feed intake and possibly poor utilization of the ground full-fat raw soybeans. Carew et al. (1961) and Carew and Nesheim (1962) also attributed depressed body weight to low feed intake in the early growth stage, and to the high cellulose content of the ground full-fat raw soybeans. It became obvious in Experiment 1 that increasing the cooking temperature from 100 to 121 C did not significantly improve the nutritive value of raw soybean as measured by weekly body weight change through 6 weeks of age. Most of the literature has focused on cooking time (McNaughton and Reece, 1980; Borchers et al., 1984, Carew et al., 1962). The lack of definitive information on the interaction of cooking time and temperature prompted Experiment 2. The cooking time-temperature combination of 60 min at 100 C resulted in a soybean product that consistently produced the heaviest chicks. Cooking time made the greatest difference in growth rate to 6 weeks of age (approximately 560 g). Growth rate was actually depressed by increasing cooking temperature of the full-fat raw soybean meal from 100 to 121 C (approximately 120 g). Renner et al. (1953) and Haywood et al. (1936) reported that excessive heat will either destroy or render unavailable several essential amino acids, particularly lysine and arginine. The consistent depression in growth rate in the current study would suggest that the full-fat raw soybean meal was over-heated when cooked at 121 C, and that the most optimal combination of temperature and cooking time evaluated was 100 C and 60 min.

In this study, feeding cooked full-fat raw soybean meal depressed growth rate significantly by 1 week of age. As the birds became older, the depressing effects of heat-treated full-fat raw soybeans on growth began to subside, suggesting that the chicks, as they grew older, were able to adjust to the cooked full-fat raw soybean meals utilized. This was particularly noticeable in Experiment 1 and in treatments 4 and 6 in Experiment 2. Alumot and Nitsan (1961) and Wood et al. (1971) recognized an age-dependent function when feeding heated full-fat soybean meal; however, this was disputed by Salmon and McGinnis (1968). Our data suggests an age-dependent function associated with cooking procedure and age of chick.

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