Replacement of soybean meal with roasted full-fat soybeans from high-protein or conventional cultivars in diets for broiler chickens[1]

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Hamilton, R. M. G. and McNiven, M. A. 2000. **Replacement of soybean meal with roasted full-fat soybeans from high-protein or conventional cultivars in diets for broiler chickens.** Can. J. Anim. Sci. **80**: 483–488. The effects were examined of replacing part or all of the soybean meal in the starter and finisher diets for male broiler chickens with ground, roasted, full-fat soybeans from either a high-protein (AC Proteus) or conventional (Baron) cultivar. The starter (1–21 d) and finisher (22–36 d) diets were formulated by replacing, on an isonitrogenous basis, part or all of the soybean meal in the barley–wheat-based control diets with the roasted soybeans. Digestibility of dry matter, corrected nitrogen and energy were estimated by an index method for the last 2 d of the starter and grower periods. Soybean level influenced body weight gains directly in a quadratic manner, and feed intakes or feed conversions by inversely linear relationships ($P < 0.05$ and $P < 0.01$) during the starter period. Performance during the finisher period or during the entire growth period was not influenced ($P > 0.05$) by dietary soybean source. Dry matter and energy digestibilities at both 21 and 35 d, and nitrogen at 35 d were affected in a quadratic manner ($P < 0.05$ or $P < 0.01$) by the soybean level of the diets, whereas, a linear relationship was present for the apparent metabolizable energy (AME) content ($P < 0.001$). Soybean source had no effect on nutrient utilization, except for dry matter or energy digestibility during the starter period ($P < 0.01$). In conclusion, the optimal performance should be obtained when the ratio of roasted full-fat soybeans to soybean meal is about 2:1 in the starter feeds for broiler chickens.

Key words: Full-fat soybeans, soybean meal, high-protein soybeans, broiler, growth, nutrient digestibilities

Hamilton, R. M. G. et McNiven, M. A. 2000. **Remplacement du tourteau de soja par des graines de soja torréfiées non dégraissées provenant d'un cultivar à haute valeur protéique ou d'un cultivar classique dans l'alimentation des poulets de chair**. Can. J. Anim. Sci. **80**: 483–488. Nous avons examiné les effets d'un remplacement partiel ou total du tourteau de soja dans les aliments de démarrage et les aliments de finition pour poulet de chair par des graines de soja broyées et torréfiées, non dégraissées provenant d'un cultivar à haute valeur protéique (AC Proteus) ou d'un cultivar classique (Baron). L'aliment de démarrage, servi de 1 à 21 j et l'aliment de finition de 22 à 36 j étaient formulés en remplaçant sur une base isoazotée tout ou partie du tourteau dans un régime à base d'orge et de blé par des graines de soja non torréfiées. Nous calculions la digestibilité de la matière sèche (m.s) de l'azote corrigé et de l'énergie par une méthode indicielle dans les deux derniers jours de la phase de démarrage et de celle de finition. La proportion de soja substituée se répercutait directement sur le gain de poids en fonction quadratique et sur l'ingéré ou sur l'indice de consommation en fonction linéaire inverse ($P < 0{,}05$ et 0,01) durant la phase de démarrage. La forme de présentation du soja n'avait pas d'effet ($P > 0{,}05$) sur les performances zootechniques, que ce soit durant la phase d'engraissement ou dans l'ensemble de la durée d'élevage. La digestibilité de la m.s. et de l'énergie à 21 et à 35 j et celle de l'azote à 35 j étaient modulées en fonction quadratique ($P < 0{,}05$ ou $P < 0{,}01$) par la proportion de soja non dégraissé dans l'aliment, tandis que la EMA (énergie métabolisable apparente) l'était en fonction linéaire ($P < 0{,}001$). La forme de présentation du soja, tourteau ou graines non déshuilées, n'avait pas d'effet sur la valorisation des nutriments, sauf celle de la m.s. et de l'énergie dans la phase de démarrage ($P < 0{,}01$). Il semble donc que les performances optimales seraient obtenues avec un rapport d'environ 2 :1 entre graines non déshuilées et tourteau de soja dans l'aliment de démarrage du poulet de chair.

Mots clés: Soja non déshuilé, tourteau de soja, soja à haute valeur protéique, poulet de chair, croissance, digestibilité

Conventional whole soybeans (*Glycine max*) contain relatively high levels of crude protein (380–420 g kg^{-1}), are a rich source of energy owing to the oil content (180–220 g kg^{-1}), and are low in fibre (approx. 50 g kg^{-1}) (Morrison

Abbreviations: **SBM**, soybean meal

[1]*Mention of a trade name, proprietary product or specific equipment does not imply its official endorsement by Agriculture and Agri-Food Canada to the exclusion of other products that may be suitable.*

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Table 1. Composition of the starter diets that contained different ratios of roasted full-fat soybeans to soybean meal

Ingredient	Soybean meal	Roasted full-fat soybeans AC Proteus 1/3	AC Proteus 2/3	AC Proteus All	Baron 1/3	Baron 2/3	Baron All
	(kg 1000 kg^{-1})						
Full-fat soybean[z]	0	137.2	274.8	412.0	169.8	340.2	510.0
Soybean meal[z]	391.0	260.8	130.2	0	260.8	130.2	0
Barley[zy]	350.0	350.0	350.0	350.0	350.0	350.0	350.0
Wheat[z]	169.0	165.0	161.0	157.0	130.3	91.7	53.0
Poultry fat	50.3	43.8	37.2	30.6	45.6	40.9	36.1
Salt	3.4	4.3	5.2	6.1	4.4	5.2	6.2
Limestone	17.1	17.2	17.3	17.4	17.2	17.2	17.3
Dicalcium phosphate	12.0	13.4	14.8	16.2	13.6	15.1	16.7
Premix[x]	5.0	5.0	5.0	5.0	5.0	5.0	5.0
DL-methionine	2.3	3.5	4.8	6.0	3.7	5.1	6.5
Total	1000.1	1000.2	1000.6	1000.3	1000.4	1000.6	1000.8
Cost, ($ t^{-1})	379.84	368.91	358.34	347.34	374.14	368.34	362.58
Determined analysis[w]							
Dry matter, (g kg^{-1})	915	922	922	914	903	906	908
Crude protein, (g kg^{-1})	244	251	246	248	243	240	239
Ash, (g kg^{-1})	64.2	60.1	60.1	63.9	62.3	63.5	64.7
Calcium, (g kg^{-1})	10.4	7.6	9.6	9.6	9.6	9.6	9.3
Total phosphorus[v], (g kg^{-1})	6.7	6.3	5.7	6.7	7.0	5.3	7.5

[z]Crude protein contents used in the formulations for soybean meal, barley and wheat were 465, 105 and 125 g kg^{-1}, respectively.
[y]All diets contained 1.5 g kg^{-1} Avizyme.
[x]Supplied per kilogram of feed: 10 000 IU vitamin A; 2000 ICU vitamin D_3; 15 IU vitamin E; 3 mg vitamin K; 8 mg riboflavin; 12 mg D-calcium pantothenate, 30 mg niacin; 1 mg folic acid; 400 mg choline chloride (50%); 5 mg pyridoxine; 3 mg thiamine; 200 µg vitamin B_{12}; 200 µg biotin; 120 mg manganese oxide (60% Mn); 90 mg zinc oxide (80% Zn); 25 mg copper sulfate (25% Cu); 0.5 mg calcium iodate (65% I); 200 mg ferrous carbonate (36% Fe), 220 µg sodium selenite (45% Se); 100 mg ethoxyquin, 680 mg Amprolium; and ground corn to dilute to 10.0 kg.
[w]The corresponding values for the KRC starter diets were 900, 234. 54.7, 10.0 and 6.7 g kg^{-1} for dry matter, crude protein, ash, calcium and total phosphorus, respectively.
[v]Calculated available phosphorus for all diets = 40 g kg^{-1}.

1959). The meal that remains after the oil is extracted from soybeans is a major source of supplemental protein used in poultry feeds (Leeson and Summers 1991). Published results indicate that properly heat-treated whole soybeans may be used effectively in poultry feeds (Waldroup 1982).

Early-maturing, cold-tolerant cultivars of soybeans that have recently been developed (Hoekstra and Ablett 1993) have increased the acreage of soybeans now grown in the Maritime Provinces of Canada (Anonymous 1997). AC Proteus is a new cultivar of soybean recently developed at Agriculture and Agri-Food Canada and registered as germplasm line OT89-16 (Voldeng and Saindon 1991). This new cultivar is primarily intended for use in animal feeds because it contains more protein (440–480 g kg^{-1} of DM) and less oil (150–180 g kg^{-1}) than conventional soybeans (380–420 g kg^{-1} CP, 180–220 g kg^{-1} oil) that were primarily developed for oil production. Agronomic characteristics and yield per hectare make AC Proteus attractive for soybean producers (Voldeng et al. 1996).

Owing to the lack of commercial soybean processing facilities in the Canadian Maritime provinces and the availability of equipment for on-farm roasting of whole soybeans (Hamilton and Thompson 1992), there is the possibility of replacing the soybean meal presently used in poultry feeds with locally grown full-fat soybeans. The results being reported are from a study to evaluate the feeding value of the high-protein soybean cultivar AC Proteus for broiler chickens by replacing part or all of the soybean meal in starter and finisher diets with roasted full-fat soybeans, and to compare this high-protein cultivar to a conventional cultivar (Baron) as a supplementary protein source for broiler chicken diets.

MATERIALS AND METHODS

A randomized complete block design was used for eight dietary treatments with six replicates. The experimental diets were formulated by replacing one-third, two-thirds or all of the commercial soybean meal (SBM) in the SBM control diet with either a high-protein (AC Proteus) or a conventional protein cultivar (Baron), the replacement was on a crude protein (N × 6.25) basis. Standard broiler starter and finisher diets of the Kentville Research Centre were included as controls (Hamilton and Proudfoot, 1995). The starter and finisher diets contained, respectively, 240 and 160 g kg^{-1} crude protein and 12.55 and 13.38 MJ kg^{-1} ME. Regardless of the source of soybean the diets contained the enzyme Beta-glucanase (1.5 g kg^{-1}) from AVIZYME 1100 (Finnfeeds International Ltd., Marlborough, UK) because of the barley content of the diets. The formulations for the soybean-containing experimental diets are summarized in Tables 1 (Starter) and 2 (Finisher).

Male day-old commercial chicks (Petersen × Arbor Acres) initially were housed in battery brooding pens (350

Table 2. Composition of the finisher diets that contain different ratios of roasted full-fat soybeans to soybean meal

		Roasted full-fat soybeans					
		AC Proteus			Baron		
Ingredient	Soybean meal	1/3	2/3	All	1/3	2/3	All
	(kg 1000 kg^{-1})						
Full-fat soybean[z]	0	58.6	117.3	176.0	72.3	144.7	217.0
Soybean meal[z]	167.0	111.4	55.6	0	111.4	55.6	0
Barley[zy]	450.0	450.0	450.0	450.0	450.0	450.0	450.0
Wheat[z]	277.0	275.7	274.0	273.0	261.4	245.6	230.0
Poultry fat	60.7	57.8	54.9	52.0	58.4	56.2	53.9
Salt	4.8	5.2	5.6	6.0	5.2	5.6	6.0
Limestone	17.5	17.6	17.5	17.6	17.6	17.5	17.6
Dicalcium phosphate	13.1	13.7	14.3	14.9	13.8	14.5	15.2
Premix[x]	5.0	5.0	5.0	5.0	5.0	5.0	5.0
DL-methionine	2.6	3.4	4.2	5.0	3.2	3.8	4.4
L-lysine	2.4	2.3	2.2	2.1	2.0	1.7	1.3
Total	1000.1	1000.7	1000.4	1000.8	1000.3	1000.2	1000.4
Cost, ($ t^{-1})	345.56	341.92	338.12	334.56	341.56	337.88	333.87
Determined analysis[w]							
Dry matter, (g kg^{-1})	906	904	905	905	904	907	911
Crude protein, (g kg^{-1})	170	167	166	168	168	166	166
Ash, (g kg^{-1})	51.0	51.1	50.3	50.2	49.9	51.7	51.2
Calcium, (g kg^{-1})	9.6	9.2	8.7	8.9	8.5	9.4	9.6
Total phosphorus[v] (g kg^{-1})	6.6	6.9	7.2	7.4	6.9	7.5	7.3

[z]Crude protein contents used in the formulations for soybean meal, barley and wheat were 465, 105 and 125 g kg^{-1}, respectively.
[y]All diets contained 1.5 g kg^{-1} Avizyme.
[x]Supplied per kilogram of feed: 10 000 IU vitamin A; 2000 ICU vitamin D_3; 15 IU vitamin E; 3 mg vitamin K; 8 mg riboflavin; 12 mg D-calcium pantothenate, 30 mg niacin; 1 mg folic acid; 400 mg choline chloride (50%); 5 mg pyridoxine; 3 mg thiamine; 200 µg vitamin B_{12}; 200 µg biotin; 120 mg manganese oxide (60% Mn); 90 mg zinc oxide (80% Zn); 25 mg copper sulfate (25% Cu); 0.5 mg calcium iodate (65% I); 200 mg ferrous carbonate (36% Fe), 220 µg sodium selenite (45% Se); 100 mg ethoxyquin, 680 mg Amprolium; and ground corn to dilute to 10.0 kg.
[w]The analyzed values for the KRC finisher diet were 910, 158, 46.8, 11.1 and 6.5 g kg^{-1} for the nutrients listed.
[v]Calculated available phosphorus for all diets = 40 g kg^{-1}.

cm × 100 cm) each of which had a thermostatically controlled heater (Peterseime Incubator Co., Gettysburg, OH); there were seven chicks per pen. Each of the six levels of cages within the batteries represented a replicate. After being weighed at 21 d of age, all live birds were re-housed in battery grower pens (700 cm × 700 cm). The battery units were located in a windowless, light-tight house. Just prior to being housed, each chick was wing banded so that its identity could be related to pen and experimental treatment.

Feed and water were available to the birds at all times during the experimental period. All birds received 24 h of light (24 lx) for the first 72 h and four cycles daily of 4 h light:2 h dark at intensities of 10 lx from 3 to 7 d and 5 lx thereafter. Initially the brooding temperature was 32°C and was reduced 3°C weekly until 20°C was reached at which temperature it remained for the duration of the experiment. The care and management of the chickens used were in accordance with the guidelines of the Canadian Council on Animal Care (1980).

Mass body weights of each pen of birds were recorded when they were 1 and 21 d of age and individual body weights at 36 d. Feed weigh-backs were done at 21 and 36 d. Mortality was recorded routinely as it occurred and the birds were necropsied by a veterinary poultry pathologist.

Two-day excreta collections were done when the birds were 20–21 and 34–35 d of age. After being collected, the excreta were frozen, freeze-dried and ground to a fine powder for chemical analysis. Samples of each of the experimental diets were collected and ground through a 1-mm screen using a centrifugal force grinder (Retch Ultra-Centrifugal Mill; F. Kurt Retch, Haan, Germany) . The diets and excreta were analyzed for dry matter, Kjeldahl nitrogen and ash using standard methods of the Association of Official Analytical Chemists (AOAC 1984); for gross energy using an adiabatic bomb calorimeter; and for acid-insoluble ash according to method described by Vogtmann et al. (1975). The diets were also analyzed for calcium and total phosphorus (AOAC 1984). Digestibility values were calculated, using the index method (Crampton and Harris 1969), for dry matter, nitrogen and energy of the excreta collected at the end of the starter and finisher periods. The uric acid content of the excreta was measured using the methods of Marquardt et al. (1983) and the apparent nitrogen digestibility values were corrected for excreta uric acid content as described by Rotter et al. (1989). Apparent metabolizable energy contents of the diets were calculated using the equation of Larbier and Leclercq (1994).

A pen was the experiment unit. The data for body weight gains, feed intake and feed conversion, mortality, economic returns and digestibility were analyzed statistically according to a randomized complete block design using ANOVA and regression models from Genstat 5 (Genstat Committee 1987). Economic returns were calculated from the revenue from the sale of birds ($1.115 kg^{-1}) minus the cost of the

Table 3. Effects of type of basal diets and dietary soybean levels or sources on the performance of broiler chickens and economic returns

Dietary	Body weight gain[z] (g)		Feed intake (kg bird^{-1})		Feed conversion (g g^{-1})		Mortality (%)		Economic returns[y]
factor	1–21 d	22–36 d	1–21 d	22–36 d	1–21 d	22–36 d	1–21 d	1–36 d	(¢ bird^{-1})
Basal diet[x]	****	NS	NS	NS	NS	NS	NS	NS	NS
KRC[w]	782	1159	1.09	2.46	1.307	1.764	1.7	2.5	33.8
SBM	727	1073	1.12	2.54	1.440	1.915	0.4	4.9	22.8
Full-fat SB	786	1070	1.14	2.44	1.355	1.829	2.4	6.4	31.4
SEM	5	15	0.02	0.08	0.019	0.027	0.01	0.02	3.4
Soybean level[x]	*,Q	NS	*,L	NS	**,L	NS	NS	NS	NS
1/3 full-fat	771	1087	1.20	2.55	1.456	1.908	4.3	7.8	25.1
2/3 full-fat	806	1086	1.14	2.33	1.329	1.771	1.2	3.1	39.7
All full-fat	780	1070	1.07	2.45	1.281	1.808	2.3	9.4	29.4
SEM	9	26	0.03	0.14	0.033	0.046	0.03	0.05	5.8
Soybean source[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
AC Proteus	787	1081	1.13	2.35	1.325	1.790	1.9	4.5	37.3
Baron	784	1058	1.14	2.54	1.358	1.868	3.1	8.7	25.5
SEM	8	21	0.03	0.13	0.027	0.038	0.04	0.06	0.055

[z]Initial body weight of chicks at housing was 48.0 ± 0.7 g.
[y]Calculated from returns from sale of birds minus the cost of the chicks plus their feed.
[x]Statistical significance for main effects: NS, not significant ($P > 0.05$), * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, and L = linear and Q = quadratic relationship.
[w] Kentville Research Centre standard starter and finisher feeds (Hamilton and Proudfoot 1995).

Table 4. Effects of type of basal diets and dietary soybean levels or sources on the apparent digestibility[z] of major nutrients and apparent metabolizable energy for broiler chickens

Dietary	Digestibilities							
	Dry matter (g kg^{-1})		Nitrogen[y] (g kg^{-1})		Energy[x] (g kg^{-1})		AME[x] (MJ kg^{-1})	
factor	21 d	36 d	21 d	36 d	21 d	36 d	21 d	36 d
Basal diet[w]	***	***	***	***	***	***	***	***
KRC[v]	680	813	496	663	729	836	13.40	14.52
SBM	697	674	555	512	737	719	13.54	12.71
Full-fat SB	736	696	629	556	770	740	14.20	13.21
SEM	3	3	6	7	3	2	0.05	0.04
Soybean level[w]	*,Q	***,Q	NS	***,Q	***,Q	***,Q	***,L	***,LQ
1/3 full-fat	741	695	627	564	772	734	13.91	13.12
2/3 full-fat	723	667	612	503	756	719	13.93	13.01
All full-fat	744	727	647	602	783	763	14.75	13.50
SEM	6	5	10	11	5	4	0.09	0.07
Soybean source[w]	***	NS	NS	NS	**	NS	NS	NS
AC Proteus	748	693	639	552	778	737	14.15	13.23
Baron	724	700	618	560	763	743	14.24	13.19
SEM	5	4	8	9	4	3	0.07	0.06

[z]Calculated by the index method (Crampton and Harris 1969) using acid-insoluble ash as the inert marker (Vogtmann et al. 1975).
[y]Corrected for uric acid content as described by Rotter et al. (1989).
[x]Calculated according to the equation published by Larbier and Leclercq (1994).
[w]Statistical significance for main effects: NS, not significant ($P > 0.05$), * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, and L = linear and Q = quadratic relationship.
[v]Kentville Research Centre Standard Starter and Finisher feeds (Hamilton and Proudfoot 1995).

chicks ($0.505 bird^{-1}) plus the feed they consumed at the cost shown in Tables 1 and 2. The roasted, full-fat soybeans were costed at $270 t^{-1}.

RESULTS AND DISCUSSION

Since there were no significant ($P > 0.05$) interactions between the main factors for the traits measured or calculated, the results are summarized by main effect (Tables 3 and 4). Type of basal diet influenced body weight gains ($P < 0.001$) among the Kentville Research Centre, SBM and full-fat soybean diets during the starter period (Table 3). The highest body weights and gains were obtained with the diets that contained the roasted, full-fat soybeans and the lowest values for the birds given the SBM-containing diet. Neither type of basal diet nor dietary full-fat soybean level influenced ($P > 0.05$) final body weights (36 d), weight gains or feed intakes and feed conversions during the finisher period (22–36 d).

Feed intakes and feed conversions were not influenced ($P > 0.05$) by the basal diet type (Table 3). However, dietary full-fat soybean level influenced ($P < 0.05$) 21-d body weights and 1–21 d weight gains in a quadratic manner. Full-fat soybean level had an inverse linear effect on both feed intake ($P < 0.05$) and feed conversion ($P < 0.01$).

The best economic returns were obtained when full-fat soybeans replaced 2/3 of the soybean meal of the control SBM diet (Table 3), although the differences were not statistically significant ($P > 0.05$). The higher economic returns obtained with the AC Proteus diets than for those containing Baron beans reflect a high-protein replacement value of the AC Proteus soybeans.

The reduced growth obtained when birds were fed the SBM control diet (Table 3) agrees with the results of Irish and Balnave (1993a), but contrasts with those of others (Waldroup and Cotton 1974; Leeson et al. 1987; Chohan et al. 1993). Irish and Balnave (1993a) found that growth of broiler chickens was consistently lower in a number of trials when SBM was the sole source of supplemental protein in sorghum-wheat based diets. Further research indicated that the water-soluble xylose content of the SBM influenced the growth of the broilers and that multi-enzyme preparations designed to act on the non-starch polysaccharide fraction of the meals did not improve growth (Irish and Balnave 1993b). An inverse relationship was indicated in the results of both Waldroup and Cotton (1974) and Leeson et al. (1987) between dietary roasted soybean levels and growth of broiler chickens during the starter period (28 or 21 d, respectively). Waldroup and Cotton (1974) concluded that this reduction in growth as the dietary soybean levels increased was due to the higher bulk density of these diets, which caused a reduction in feed intakes. Feed intakes also decreased as the level of soybean in the diet increased (Leeson et al. 1987). Both 7–21d feed intakes and body weight gains were lower when Chohan et al. (1993) replaced, on a weight basis, the soybean meal in a control diet with autoclaved full-fat soybeans in diets for broiler chickens. Chohan et al. (1993) used the same soybean cultivar as was used in the present study (Voldeng et al. 1996).

Dry matter, nitrogen and energy digestibility values for both the 20–21 and 34–35d excreta collections were influenced ($P < 0.001$) by basal diet type (Table 4). For the starter period, these dietary components were utilized better by the birds given diets containing the full-fat soybeans, but in the finisher period higher values occurred with the chickens fed the Kentville Research Centre diets. The level of full-fat soybeans in the diets affected the digestibility results in a quadratic manner ($P < 0.05$ to $P < 0.001$), except for the 21-d nitrogen values ($P > 0.05$). However, the relationship was linear ($P < 0.001$) between dietary soybean level and AME content. The average measured AME contents of the experimental starter diets were 11.7% higher than the formulated values (12.55 MJ kg^{-1}), while the energy values of the finisher diets averaged 0.6% lower than the estimated value of 13.35 MJ kg^{-1}. The measured ME values reported by Leeson et al. (1987) were also higher (6.3–12.5%) than the calculated energy content of their diets. The differences in the nutrient utilization between the two varieties of full-fat soybeans used in this experiment were small ($P > 0.05$). Previous results reported by Nesheim et al. (1962), Saxena et al. (1963) and Leeson et al. (1987) indicate that the effects of including full-fat soybeans in the diets of broiler chickens were less for older than for younger birds. In the present study, dietary level of full-fat soybeans had little influence on performance (Table 3) or nutrient utilization (Table 4). In contrast, Waldroup and Cotton (1974) recommended that the level of cooked full-fat soybeans be limited to 25% or less in diets that are fed in the all-mash form. The starter and finisher diets used in the present experiment contained up to 510 and 217 g kg^{-1}, respectively, roasted full-fat soybeans (Tables 1 and 2).

In conclusion, full-fat high-protein soybean varieties, such as AC Proteus and Baron, may replace soybean meal as a source of supplemental protein in broiler starter feeds. Optimal performance of birds should be obtained when the ratio of full-fat soybeans to soybean meal is about 2:1 in the starter feeds.

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