Turkish Journal of Agriculture - Food Science and Technology, 12(6): 991-998, 2024
DOI: https://doi.org/10.24925/turjaf.v12i6.991-998.6783

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Effects of Partially Replacing the Commercial Soybean Meal, With A Soaked and Boiled Raw Full-Fat Soybean in Broiler Diets

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ARTICLE INFO

Research Article

Received : 18.03.2024
Accepted : 05.05.2024

Keywords:
Anti-nutritional factors
Raw soybean
Boiling
Soaking
Partial replacement

ABSTRACT

The aim of this study was to investigate the effects of partially replacing the commercial soybean meal (SBM) with a home-treated, locally produced raw-full fat soybean (RFFSB) in the diets of broilers. A 3×2×2+1 factorial arrangement was used to conduct this feeding trial. A test ingredient (RFFSB) was differently soaked (0, 6 or 12 hrs), drained, boiled (25 or 35 min) and sundried. Following this, it was hammered to pass through a 0.2-mm sieve, then 12 experimental diets were formulated, replacing the SBM by such a home-treated-RFFSB at 50 or 75%. The control diet didn't contain any RFFSBN. Totally 13 experimental diets were prepared and every treatment was replicated 3 times and 10 chicks per replicate. The results revealed that replacing the commercial SBM by a treated RFFSB had no significant interaction effects on any measured parameter. However, soaking and then boiling it (RFFSB) had significant ($P<0.05$) interaction effect on the BWTG (1-13d and 14-28d). When increasing the soaking time, the FI (feed intake), BWTG (body weight gain) and feed efficiency were significantly ($P<0.05$) decreased. When increasing the boiling duration, both FI and feed efficiency (14-28d) were improved. But, when increasing the replacement rate of RFFSB, the feed efficiency was deteriorated. Broilers fed on both control and diets, containing a non-soaked RFFSB had higher ($P<0.05$) BWTG (1-13d). Birds fed on diets containing RFFSB that was soaked for the longest period (12 hrs) had significantly lower BWTG. Birds fed on diets, containing prolonged boiling duration had significantly ($P<0.05$) higher BWTG and feed efficiency. There was no interaction ($P> 0.05$) effect on both carcass yield and cut-products. Neither increasing a boiling time nor a replacement rate had ($P<0.05$) any influence on the WT (weight) of the carcass. Birds on both control and on non-soaked RFFSB diets had better WT of carcass products. There was no interaction ($P>0.05$) effect on organ developments. However, increasing the soaking-duration significantly ($P<0.05$) reduced the organ developments. Therefore, it is concluded that commercial SBM can be replaced by a non-soaked, but boiled raw soybean in diets of broilers.

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Introduction

Lack of both quality and sufficient quantity of chicken feeds are the bottleneck problems that have been hindering chicken production improvements, particularly in underdeveloped countries (Mammo and Wude, 2022). Although soybean meal (SBM) is currently one of the best protein-source feed ingredients, this ingredient is generally expensive and sometimes unavailable to some pocket areas. In some areas, for example in Ethiopia, the raw full-fat soybean (RFFSB) is sometimes cheaper than the commercial SBM (i.e., a byproduct after extracting the oil). However, the RFFSB contains a variety of anti-nutritional factors (ANFs) which limit the proper utilization of the nutrients, specifically by non-ruminant animals (ASA, 2004; Mammo, 2019; Mammo et al., 2019). Resisting the negative effects of these ANFs by the birds can also vary based on their age and the concentration of ANFs (ASA, 2004; Erdaw, 2023; Mammo and Shambel, 2024). A commonly known ANFs in the raw-soybean-seeds are protease inhibitors, lectins and phytate (Pettersson and Pontoppidan, 2013).

Protease (trypsin) inhibitors can interfere with the biological activity of endogenous protease and thereby reduce the digestion of proteins (Nahashon and Kilonzo Nthenge, 2013; Erdaw, 2023). Trypsin inhibitors and lectins also inhibit the activities of protease-enzymes in the digestive tract, thereby reduces the protein digestion in non-ruminant animals as well as in the young ruminants (Liener, 1994; Liu et al., 1998). Consumption of raw beans increased the size of the pancreas and the duodenum and thereby reduced both feed consumption and the growth of the chicks. Scholars (Mogridge et al., 1996; ASA, 2004; Erdaw et al., 2017a) reported that diets of the birds, containing raw beans reduced their feed consumption and live weights and also decreased the feed conversion indices.

To some extent, broiler chickens can adapt to ANFs in the diet with age advances (Rao et al., 2009). Petričević et al. (2014) also added that the differences in birds' body weights, food consumption, occurrence of defective eggs and the relative weight of the pancreas were not significantly influenced by ANFs in the raw soybean. However, other research scholars (Latshaw & Clayton (1976; Erdaw, 2018; Erdaw et al., 2017b) added that birds' pancreas weights increased at a proportional rate of increasing an inclusion rate of raw soybeans (Mogridge *et al*., 1996). Furthermore, soybean contains a high concentration of carbohydrates, including NSP and oligosaccharides (Zdunczyk et al., 2011), which also can negatively influence soybean utilization. Carbohydrates make up approximately 35% of soybean seeds and 40% of SBM. Half of the percentage is non-structural, in the form of oligosaccharides, and a small amount is structural polysaccharides.

However, Adeleke et al. (2017) reported that soaking and boiling of the seeds, containing ANFs, for example groundnut could improve the nutritive values. Yassin et al. (2014) also added that feeding different replacement levels of the raw, full-fat soybean after soaking and heating resulted in a better productive performance of broilers at all marketing ages. Cooking of soaked seeds resulted in higher losses of anti-nutrients in comparison to un-soaked seeds (Sharma et al., 2013). Due to heat-treatment (150°C for 30 minutes) of the soybean flour reduced the trypsin inhibitor activity and urease, but it did not affect protein solubility (Carvalho et al., 2013).

In Ethiopia, locally produced raw soybean (grains) is sometimes cheaper, particularly in the pocket-areas than the commercial soybean meal (SBM). The expensiveness of SBM is further exaggerated in the remote areas (from the center) and in places where there are no sufficient oil-extracting plants. Sometimes, a double transportation cost is also incurred against the producers. This means, firstly when transporting the raw soybean grain towards to the oil-extracting plant, and also when returning back the byproducts (SBM) to the chicken producers, as a feed. The oil-extracting plants are mostly installed near the big-cites, which are far from the major grain-producing areas. Because of all these facts, this study was therefore, planned to investigate the effects of replacing the commercial soybean meal by that of a home-treated raw soybean, at least to reduce the feed-cost of broiler production, and thereby to contribute for the better delivery of chicken meat to the consumers.

Objective

To evaluate the replacement values of commercial soybean meal with that of a soaked as well as boiled raw-full-fat soybean in diets of broilers

Materials and Methods

Preparation of Both a Test Ingredient and The Experimental Diets

Immediately after harvest, the raw soybean grain (full fatted) was bought from a local market and then cleaned. The seed was then divided into 3 equal parts followed by soaking for 0, 6 or 12 hrs, respectively. The temperature of the water, which was used to soak the seed was around 4.5°C (i.e., it was neither warmed nor cooled). Equal amount of water (2/3 of the seed, by weights) was used for each of the above group to being soaked. Each of the above group (soaked seed for 0, 6 or 12 hrs) was also immediately drained and then further divided into 2 equal parts.

Once again, each of these parts was subjected to being boiled for 25 or 35 minutes. An equal amount of water (3/4 of the seed, by weight) was boiled, up to a 100-degree-celsius before putting the measured seed into a boiled water and then waited for either 25 or 35 minutes. The same barrel was used to boil the water that was also fueled/heated by the firewood. The process of adding the firewood, under the barrel of a boiling-water was kept-consistent throughout the period (i.e., 25 or 35 minutes) that it was trying to keep the consistency of the temperature in the barrel.

Table 1. Ingredients and major nutrient composition per each treatment for the starter diets of the broiler chickens (e.g.)

Soaking times (hrs)	0				6				12				Control
Boiling times (min)	25		35		25		35		25		35		
Replacement (%)	50	75	50	75	50	75	50	75	50	75	50	75	
Treatments	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}
Ingredients (kg):													
Maize	57.1	56.6	57.1	56.6	57.1	56.6	57.1	56.6	57.1	56.6	57.1	56.6	58.8
Soybean meal	15	7.5	15	7.5	15	7.5	15	7.5	15	7.5	15	7.5	30
Raw soybean	15	22.5	15	22.5	15	22.5	15	22.5	15	22.5	15	22.5	0
Soybean-Oil	0.75	0	0.75	0	0.75	0	0.75	0	0.75	0	0.75	0	1.3
Dicalcium phosphate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Meat and bone meal	8.75	10	8.75	10	8.75	10	8.75	10	8.75	10	8.75	10	6.5
Limestone	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Methionine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Lysine	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Premix	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total	100	100	100	100	100	100	100	100	100	100	100	100	100
Nutrient composition :													
CP%	20.85	20.76	20.86	20.97	20.96	20.96	20.96	21.03	20.96	20.96	20.96	20.96	21.10
ME, kcal/kg	3194	3194	3145	3121	3079	3078	3120	3146	3120	3078	3120	3078	3087

NB: Raw, full-fat soybean (RFFSSB) was subjected to be soaked followed by boiling before used to replace the commercial soybean meal in these broiler diets

Table 2. Chemical composition of both raw, full-fat soybean and commercial SBM (%)

Parameters	Raw, full-fat soybean	Commercial SBM
Dry matter	92.4	91.5
Crude proteins	38.2	42
Crude fiber	6.2	3.8
Ether extract	14.7	1.9
Calculated AME, MJ/kg)	12.6	9.0

Immediately after finishing the duration of the boiling time, it was then drained and subjected to sun-drying. This drying process was facilitated by thinly spreading the soaked grains on the canvas-sheet. A serious follow-up was also carried-out to avoid any development of the fungus/molds on such processed products. A dried RFFSB was hammered to passing through a 0.2 mm sieve. Subsequently, 12 experimental diets were formulated by replacing the commercial SBM with the treated and then dried RFFSB. A control diet, which didn't contain any RFFSB was also formulated. All these diets were formulated while keeping the *iso-caloric and iso-nitrogenous* contents of the diets (Table 1) that was trying to satisfy a minimum nutrient requirements (at least the minimum) of the birds. While replacing the commercial SBM with that of a treated-RFFSB the content of the crude protein (CP%), in the experimental diets, were balanced using meat and bone meal.

Finally, a 3×2×2+1 factorial arrangement, which was soaking of RFFSB at 3 levels (0, 6 or 12 hrs), followed by 2 levels (25 or 35 minutes) of boiling (i.e., after draining a soaked RFFSB) and then 2 levels (50 or 75%) of replacing the commercial SBM by RFFSB and a control diet was used. The control diet did not contain any RFFSB.

Experimental House/Pens and Animal Managements

Firstly, this feeding trial was approved by the Animal Research Ethical Review Committee (Certificate Ref: No: VM/ERC/45/ 03/15/2023). The bedding-straw and other utensils as well as experimental pens were sprayed with recommended chemicals and this all were done 2 days before the arrival of the chicks. Each pen is wide enough for the birds and *teff-straw* was used as the bedding materials. Each pen had an INFRA-RED bulb to warm the room. Just before arriving the chicks, starter diets and water were offered in every pen. Initial BWT was recorded immediately after the arrival of those one-day-old broiler chicks (Cobb-500). These birds were then randomly allocated on the 13 experimental diets, which were replicated 3 times with 10 birds per pen. All necessary vaccinations were given. Room temperature was uniformly controlled by adjusting the equal heights of the bulb in every pen. Every offered and refused diets were weighed and recorded.

Data Collections

Every feed offered to birds (per pen) was weighed and it was *ad libitum*. The refused feed was also weighed per pen to compute the feed intake (FI). The average body weight gain (BWTG) was recorded per pen and then to calculate the feed conversion ratio (FCR).

At the end of the study, one per pen and 3 birds per treatment were randomly selected and weighed and then humanly slaughtered to evaluate the effects of partially replacing the commercial SBM by the treated raw soybean on the development of internal organs. Some of the vital internal organs, such as the pancreas, duodenum and intestines were weighed and then evaluated as g/100 g of the corresponding sampled BWT of the birds. Simultaneously, the characteristics of both carcass yield and its parts were also evacuated from these same slaughtered birds.

Statistical Analysis

Descriptive statistics and general linear model (GLM) were used to analyze the data with SPSS (MBI). The data from the feeding trial were analyzed using the general linear model (GLM) to evaluate the soaking, boiling and replacement rates. The differences were considered to be significant at $p < 0.05$, and the significant differences between mean values were separated using the Tukey (a-b). Results of the control group (i.e., an approach of factorial arrangements, with that of a plus control) were computed as described by Marini (2003).

Results

Major nutrients, which are found from the analysis of chemical composition of the sampled raw, full fat soybean and commercial soybean meal are given in Table 2: Therefore, the crude protein values of RFFSB and SBM are 38.2 and 42%, respectively and these values are almost equivalent. Results of an ether-extract and apparent metabilozeable energy are also found to be maximum for the sample of RFFSB (Table 2).

Results in response to the effects of boiling a soaked raw, full-fat soybean and its replacement values on birds' FI, BWTG and FCR are shown in Table 3.

The Gross Performance of Birds in Response to Interaction Effects

Differently treating the RFFSB, as the main effects (soaking, boiling or replacement) had no significant ($P>0.05$) interaction effects on any measuring parameter of this broiler production. However, a differently soaking of the RFFSB and then boiling it had significant ($P<0.05$) interaction effect on the BWTG (at 1-13d and 14-28d) of the birds. Boiling and replacing (at the graded level) of the RFFSB had significant ($P<0.05$) effects on the both BWT and feed efficiency of broiler production, at an early age of the birds.

The Gross Performance of Birds in Response to the Main Effects

When increasing soaking duration/time, as a main effect, it significantly ($P<0.05$) decreased both FI and BWTG, across all the trial-phases (starter, grower and finisher phases). Increasing the soaking time also proportionally reduced the feed efficiency of the birds.

Table 3. Effects of partially replacing the commercial SBM with a soaked and then boiled raw soybean in diets of broilers.

Soak (hrs)	Boil (min)	Replace (%)	Feed intake (g)				Body weight gains (g)				Feed conversion ratio			
			1-13d	14-28d	29-46d	1-46d	1-13d	14-28d	29-46d	1-46d	1-13d	14-28d	29-46d	1-46d
0	25	50	374.3^{a}	1417.7^{a}	3076.8	4903.1	214.0^{a}	966.9^{a}	1574.7^{ab}	2700.9^{a}	1.8^{bc}	1.5^{c}	2.0	1.8^{c}
		75	369.3^{ab}	1344.0^{ab}	2940.8	4654.1	197.3^{ab}	895.5^{a}	1534.2^{ab}	2468^{ab}	1.9^{bc}	1.5^{c}	1.9	1.9^{c}
	35	50	358.0^{ab}	1347.5^{ab}	3060.7	4766.2	214.2^{a}	977.3^{a}	1554.1^{ab}	2571^{ab}	1.7^{c}	1.4^{c}	2.0	1.9^{c}
		75	353.7^{abc}	1338.6^{ab}	3096.1	4788.4	186.3^{ab}	923.8^{a}	1489.1^{b}	2452^{ab}	1.9^{bc}	1.5^{c}	2.1	2.0^{bc}
6	25	50	336.0^{abc}	1315.0^{ab}	2878.4	4529.4	167.3^{b}	780.0^{b}	1444.6^{b}	2263.2^{b}	2.0^{bc}	1.7^{bc}	2.0	2.0^{bc}
		75	318.3^{c}	1179.3^{b}	3040.8	4538.5	129.7^{c}	589.7^{c}	1507.9^{ab}	2137^{bc}	2.5^{ab}	2.0^{ab}	2.0	2.1^{bc}
	35	50	343.7^{abc}	1309.7^{ab}	3399.8	5053.2	181.7^{ab}	883.9^{ab}	1543.1^{ab}	2465^{ab}	1.9^{bc}	1.5^{c}	2.2	2.1^{bc}
		75	327.7^{bc}	1255.0^{ab}	2817.8	4400.5	156.0^{c}	712.7^{b}	1449.1^{b}	2200^{bc}	2.1^{b}	1.8^{b}	2.0	2.0^{bc}
12	25	50	348.0^{abc}	1260.2^{ab}	2918.8	4527.1	162.9^{bc}	735.2^{b}	1288.4^{bc}	2063^{bc}	2.1^{b}	1.7^{bc}	2.3	2.2^{bc}
		75	303.0^{d}	1299.6^{ab}	2952.5	4555.2	117.7^{d}	518.7^{c}	1168.5^{c}	1725.8^{d}	2.6^{a}	2.5^{a}	2.5	2.6^{a}
	35	50	328.7^{bc}	1279.1^{ab}	2993.6	4601.4	159.7^{c}	732.3^{b}	1380.5^{b}	2152^{bc}	2.1^{b}	1.7^{bc}	2.2	2.1^{bc}
		75	302.3^{d}	1266.8^{ab}	2820.8	4389.9	112.0^{d}	561.8^{c}	1241.4^{bc}	1841.9^{c}	2.7^{a}	2.3^{ab}	2.3	2.4^{ab}
Control			366.4^{ab}	1386.1^{a}	3019.7	4772.2	215.4^{a}	975.6^{a}	1645.2^{a}	2659.8^{a}	1.7^{c}	1.4^{c}	1.8	1.8^{c}
Pooled SEM			4.21	13.07	39.94	46.77	5.82	26.03	26.57	50.29	0.06	0.06	0.05	0.05
Main effects														
0			363.8^{a}	1361.9^{a}	3044^{a}	4777.9^{a}	203.0^{a}	940.9^{a}	1538.0^{a}	2547.8^{a}	1.8^{c}	1.5^{c}	2.0^{b}	1.9^{b}
6			331.4^{b}	1264.8^{b}	3034^{a}	4630.4^{b}	158.7^{b}	741.6^{b}	1486.2^{a}	2266.4^{b}	2.1^{b}	1.7^{b}	2.0^{b}	2.0^{b}
12			320.5^{b}	1276.4^{b}	2921^{a}	4518.4^{b}	138.0^{c}	637.0^{c}	1269.7^{b}	1945.5^{c}	2.4^{a}	2.1^{a}	2.3^{a}	2.4^{a}
	25		341.5^{a}	1302.6^{a}	2968^{a}	4617.9^{a}	164.8^{a}	747.6^{b}	1419.7^{a}	2226^{a}	2.1^{a}	1.8^{a}	2.1^{a}	2.1^{a}
	35		335.7^{a}	1299.5^{a}	3032^{a}	4666.6^{a}	168.3^{a}	798.6^{a}	1442.9^{a}	2280^{a}	2.1^{a}	1.7^{b}	2.1^{a}	2.1^{a}
		50	348.1^{a}	1321.5^{a}	3055^{a}	4730.1^{a}	183.3^{a}	845.9^{a}	1464.2^{a}	2369.1^{a}	1.9^{b}	1.6^{b}	2.1^{a}	2.0^{b}
		75	329.1^{b}	1280.6^{b}	2945^{a}	4554.4^{b}	149.8^{b}	700.3^{b}	1398.4^{a}	2137.4^{b}	2.3^{a}	1.9^{a}	2.1^{a}	2.2^{a}
Pre-determined contrasting														
Control vs diet + RFFSB			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sources of variations														
Soaking			0.00	0.00	0.361	0.00	0.042	0.030	0.001	0.000	0.000	0.000	0.012	0.002
Boiling			0.267	0.876	0.413	0.552	0.437	0.003	0.532	0.225	0.177	0.028	0.916	0.48
Replacement			0.001	0.054	0.162	0.04	0.000	0.000	0.084	0.000	0.000	0.000	0.800	0.029
Soaking×boiling			0.149	0.31	0.64	0.451	0.041	0.03	0.448	0.132	0.152	0.513	0.375	0.446
Soak×replace			0.064	0.111	0.651	450	0.101	0.003	0.443	0.338	0.31	0.000	0.491	0.146
Boil×Replace			0.501	0.446	0.101	0.205	0.951	0.381	0.369	0.993	0.898	0.401	0.697	0.471
Soak×Boil×Replace			0.726	0.359	0.066	0.081	0.560	0.915	0.686	0.494	0.278	0.548	0.626	0.768

^{a,b,c,d} Means bearing uncommon superscripts within a column are significantly different. RFFSB= raw, full-fat soybean. SBM = commercial soybean meal. Soaking (i.e., RFFSB was soaked at 0, 6 or 12 hrs), and then this soaked RFFSB was then boiled at 25 or 35 min. SBM was replaced by RFFSB at 50% or 75% , equivalent to 75 and 225 g/kg of diet, respectively); NS= not significant; SEM= pooled standard error of means

The trend of the results showed that increasing the boiling durations (from 25 to 35 min) of the RFFSB resulted in an increased FI. Feed efficiency was also improved when increasing the boiling duration, particularly at 14-28 days of age. Although the trend was not continuing, generally it showed that increasing the replacement rate (from 50 to 75%) of the treated RFFSB reduced the birds' BWTG. When increasing a replacement rate (from 50 to 75%) of RFFSB (i.e., treated RFFSB) the feed efficiency was also deteriorated.

The Gross Performance of Birds in Response to the Variation of the Treatment Groups

The result revealed that broilers fed on the control diet as well as on diets, containing a boiled, but a non-soaked raw soybean consumed maximum amounts of feeds, at their early age (1-13 days of age). However, when the age of the birds becoming advanced (14-28 days of age), there was no significant (P>0.05) difference in feed intakes, except for those birds fed on T_6 (a diet containing RFFSB that was soaked for 6 hrs and then boiled for 25 minutes, with 75% replacement). When the age of the birds was further advanced (29-49 days) there was no significant (P > 0.05) difference in the feed intakes of the birds, across the treatment groups.

Broilers fed on the control diet as well as on diets, containing a non-soaked raw soybean (i.e., but it was boiled for either 25 or 35 min and also the replacement rate was either 50 or 75%) had significantly (P<0.05) higher BWTG as compared to other birds, at their early age (1-13 days of age). However, exceptionally those birds fed on T_7 (a RFFSB that was soaked for 6 hrs and then boiled for 35 min, with 50% replacement) also had no significant (P> 0.05) difference in BWTG with the birds on the control diet as well as on diets containing a non-soaked RFFSBN. Birds fed on diets containing a soaked RFFSB (12 hrs) had significantly lower BWTG.

Birds fed on diets, containing RFFSB (boiled for 35 min) had significantly (P <0.05) higher BWTG than other birds fed on RFFSB (boiled for 25 min). Although birds fed on diets, containing a boiled (35 minutes) RFFSB had better FI (1-46 days of age) and better BWG (across all phases), there was no significant (P>0.05) difference between the treatment groups. When increasing the boiling time (for example at 14-28d), the feed efficiency was significantly (P<0.05) improved. Generally, the feed efficiency was improved against to an increasing soaking duration.

Table 4. Effects of partially replacing SBM with a soaked and boiled raw soybean on weights of the carcass parts.

Soak(hrs)	Boil(min)	Replac (%)	BWT	Dressed	Carcass	Thigh	drumstick	Wing	Breast
0	25	50	3233.6^{a}	2964.5^{a}	2510.1^{a}	338.6^{a}	307.5^{a}	198.1	655.2
		75	2907.3^{ab}	2703.1^{ab}	2287.3^{ab}	329.7^{ab}	304.4^{a}	172.6	825.2
	35	50	2962.9^{ab}	2715.3^{ab}	2311.1^{ab}	337.7^{a}	278.3^{ab}	175.4	878.2
		75	2790.6^{ab}	2573.3^{a}	2168.5^{b}	306.0^{ab}	283.1^{abc}	171.8	758.1
6	25	50	2694.8^{ab}	2503.4^{b}	2111.6^{b}	305.2^{ab}	271.5^{abc}	169.3	746.0
		75	2412.5^{bc}	2223.5^{c}	1816.0^{c}	257.4^{b}	238.7^{abc}	144.5	672.2
	35	50	2813.5^{ab}	2604.8^{a}	2189.7^{c}	298.4^{ab}	265.8^{abc}	173.8	790.2
		75	2593.5^{ab}	2390.2^{b}	2013.9^{b}	271.6^{b}	252.2^{abc}	157.4	687.9
12	25	50	2454.3^{bc}	2277.8^{bc}	1886.9^{c}	255.3^{b}	241.8^{abc}	149.7	732.3
		75	2110.8^{c}	1959.2^{c}	1605.8^{c}	234.2^{c}	209.7^{cd}	130.9	538.2
	35	50	2456.8^{bc}	2283.7^{bc}	1945.5^{b}	264.1^{b}	228.2^{b}	158.2	723.9
		75	2125.2^{c}	1966.7^{c}	1605.2^{c}	217.2^{c}	201^{d}	126.3	553.2
Control			3084.0^{ab}	2878.8^{ab}	2510.1^{a}	343.8^{a}	299.9^{a}	187.9	768.2
SEM			61.5	56.5	51.9	7.9	6.4	27.2	26
Main effects									
0			2973.6^{a}	2739.1^{a}	2319.2^{a}	328.0^{a}	293.3^{a}	179.5	779.2
6			2628.6^{b}	2430.5^{b}	2032.8^{b}	283.1^{b}	257.0^{b}	161.3	724.1
12			2286.8^{c}	2121.9^{c}	1760.9^{c}	242.7^{c}	220.2^{c}	141.3	636.9
	25		2833.6	2613.8	2200.8	312.4	280.6	171.9	755.8
	35		2425.7	2247.1	1874.5	256.8	233.1	149.4	671
		50	2833.6	2613.8	2200.8	312.4	280.6	171.9	755.8
		75	2425.7	2247.1	1874.5	256.8	233.1	149.4	671
Pre-determined contrasting									
Control vs diet + RFFSBM			NS	NS	NS	NS	NS	NS	0.05
Sources of variations:									
Soaking			0.00	0.003	0.002	0.00	0.00	NS	NS
Boiling			NS	NS	NS	NS	NS	NS	NS
Replacement			NS	NS	NS	NS	NS	NS	NS
Soaking×boiling			NS	NS	NS	NS	NS	NS	NS
Soak×replace			NS	NS	NS	NS	NS	NS	NS
Boil×Replace			NS	NS	NS	NS	NS	NS	NS
Soak×Boil×Replace			NS	NS	NS	NS	NS	NS	NS

a,b,c,d Means bearing uncommon superscripts within a column are significantly different. RFFSB= raw, full-fat soybean. SBM = commercial soybean meal. Soaking (i.e., RFFSB was soaked at 0, 6 or 12 hrs), and then this soaked RFFSB was then boiled at 25 or 35 min. SBM was replaced by RFFSB at 50% or 75%, equivalent to 75 and 225 g/kg of diet, respectively); NS= not significant; SEM= pooled standard error of means

Results in birds' response to feeding a soaked and then boiled raw, full-fat soybean with a graded replacement rate, particularly on weights of the carcass parts are shown in Table 4. There was no interaction (P > 0.05) effect of which due to treating (graded levels of soaking, boiling or partial replacing) of the raw soybean on the WT of the carcass and its parts of broilers. Except for the wing and breast, increasing a soaking duration significantly (P<0.05) reduced the WT of the carcass and its parts in this broiler production. Neither of increasing the boiling times nor replacement rate had no (P<0.05) any influence on the WT of the carcass or its parts.

Birds fed on diets, containing RFFSB that was soaked for 12 hrs performed inferior in carcass WT and its parts. The trends showed that when increasing the soaking durations, the WT of dressed, carcass and its parts were reduced. Generally, birds on both control diets and on the diets, containing a non-soaked RFFSB had better products (WT of products, such as dressed-carcass, carcass, thigh and drumstick). However, wing and breast were not significantly (P >0.05) influenced by any treatment of the RFFSB.

Results, in birds' response to the effects of boiling a soaked raw, full-fat soybean and its replacement values, on weights of internal organ developments are shown in Table 5. There were no interaction (P>0.05) effects of which due to treating (graded levels of soaking, boiling or partial replacing) of the raw soybean on WT of organ developments of the broiler chickens. Increasing soaking durations significantly (P<0.05) reduced the WT of organ developments. Except for the WT of an intestine, increasing the replacement rate had no significant (P> 0.05) difference on any other organ development. Increasing the boiling duration had no (P>0.05) influence on any organ development.

Birds fed on diets, containing a treated RFFSB (i.e., a RFFSB that was soaked for 12 hrs and 75% replacement) experienced significantly (P<0.05) higher WT of intestine, pancreas and duodenum, as compared to organs of other birds.

Discussion

Broilers fed on the control diet as well as on diets, containing boiled, but a non-soaked raw soybean consumed maximum amounts of feeds, at their early age (1-13 days of age). This result is in line with Heger et al. (2016), who reported that as broilers fed on treated RFSB, with increased temperature had better growth performance and a decreased pancreas weight. However, when the age of the birds' became e advanced, there was no significant difference on feed intakes. This current result agrees with other scholars (Ravindran & Abdollahi, 2021; Erdaw et al., 2016; Mammo and Shambel, 2024), who reported that a limiting factor of chicken production are the less secretion and activities of the digestive enzymes, and the surface area for absorption and these limitations are overcome as the birds grow older.

Table 5. Effects of partially replacing the commercial SBM by a soaked and boiled raw soybean on the organ development (in wts, g) of broiler chickens.

Soak (hrs)	Boil (min)	Replace (%)	Live BWT/sampled bird	Intestines	Duodenum	Pancreas
0	25	50	3233.6^{a}	3.6^{b}	076^{ab}	0.23^{c}
		75	2907.3^{ab}	4.2^{b}	0.67^{ab}	0.23^{c}
	35	50	2962.9^{ab}	3.7^{b}	0.58^{b}	0.25^{b}
		75	2790.6^{ab}	3.9^{b}	0.65^{b}	0.26^{b}
6	25	50	2694.8^{ab}	4.1^{b}	0.70^{ab}	0.33^{b}
		75	2412.5^{bc}	4.6^{b}	0.70^{ab}	0.31^{b}
	35	50	2813.5^{ab}	3.8^{b}	0.72^{ab}	0.26^{b}
		75	2593.5^{a}	4.4^{b}	0.70^{ab}	0.28^{b}
12	25	50	2454.3^{bc}	4.3^{b}	0.74^{ab}	0.33^{b}
		75	2110.8^{c}	5.0^{ab}	0.92^{ab}	0.37^{ab}
	35	50	2456.8^{c}	4.2^{b}	0.82^{ab}	0.32^{b}
		75	2125.2^{c}	5.9^{a}	1.04^{a}	0.4^{a}
Control	0	0	3084.0^{ab}	3.9^{b}	0.69	0.25^{b}
SEM			61.5	2.5	0.6	0.2
Main effects						
0			2973.6^{a}	3.83^{b}	0.66^{b}	0.24^{b}
6			2628.6^{b}	4.25^{b}	0.70^{b}	0.29^{b}
12			2286.8^{c}	4.82^{a}	0.88^{a}	0.36^{a}
	25		2833.6	4.3	0.75	0.3
	35		2425.7	4.3	0.75	0.29
		50	2833.6	4.0^{b}	0.72	0.29
		75	2425.7	4.6^{a}	0.78	0.31
Pre-determined contrasting						
Control vs diet + RFFSBM			NS	NS	NS	NS
Sources of variations						
Soaking			0.00	0.00	0.001	0.001
Boiling			NS	NS	NS	NS
Replac			NS	0.00	NS	NS
Soaking×boiling			NS	NS	NS	NS
Soak×replace			NS	NS	NS	NS
Boil×Replace			NS	NS	NS	NS
Soak×Boil×Replace			NS	NS	NS	NS

a,b,c Means bearing uncommon superscripts within a column are significantly different. RFFSB= raw, full-fat soybean. SBM = commercial soybean meal. Soaking (i.e., RFFSB was soaked at 0, 6 or 12 hrs), and then this soaked RFFSB was then boiled at 25 or 35 min. SBM was replaced by RFFSB at 50% or 75% , equivalent to 75 and 225 g/kg of diet, respectively); NS= not significant; SEM= pooled standard error of means

Broilers fed on the control diet as well as on diets, containing a non-soaked raw soybean had significantly (P<0.05) higher BWTG as compared to other birds, at their early age. This current result disagrees with Sharma et al. (2013), who reported that cooking of soaked seeds resulted in higher losses of anti-nutrients in comparison to un-soaked seeds. Increasing the boiling time of RFFSB improved the feed efficiency. Generally, the feed efficiency was improved against to an increasing soaking duration. But, other scholars (Yassin et al., 2014; Adeleke, et al., 2017) reported that soaking and boiling of the seeds containing ANFs, had a better productive performance of broilers at all marketing ages. Birds fed on diets containing a soaked RFFSB (12 hrs) had significantly lower BWTG. This current result disagreeing with Sharma et al. (2013), who reported that cooking of soaked seeds resulted in higher losses of anti-nutrients in comparison to un-soaked seeds.

Birds fed on diets, containing a treated RFFSB (i.e., a RFFSB, which was soaked for 12 hrs and 75% replacement) experienced significantly (P<0.05) higher WT of intestine, pancreas and duodenum, as compared to other birds. This current result agrees with Erdaw et al. (2017), who reported that when increasing the amounts of RFFSB enabled to increase in the WTs of the pancreas, duodenum and intestines. This current result is also in line with Humyra et al. (2018), who reported that increasing soaking time from 4 to 6 h did not show any significant difference in terms of anti-nutritional activities.

Conclusion and Recommendations

Replacing the commercial SBM with a home-treated RFFSB had no significant interaction effects on any measurable parameter of broiler production. Either boiling or replacement of RFFSB had no significant effects on any performance-measuring parameter. When increasing the soaking time/duration the gross response of broilers decreased across all trial-phases. Increasing the boiling durations increased both the FI and efficiency (14-28d). Broilers fed on both control and diets, containing a non-soaked RFFSB had higher BWTG (1-13d). There were no interaction effect on the carcass and its parts. Neither increasing that of the boiling durations nor replacement rate had no influence on the WTS of the carcass or its parts. There was no any interaction effect on the WT of organ developments. However, increasing a soaking duration significantly reduced the WT of organ developments. Therefore, it is recommended that commercial SBM can be replaced with a non-soaked, but boiled raw soybean in the broiler diets. Further testing is also recommended with prolonged boiling duration and it is also better to taste it at commercial production level. A total broiler production cost, particularly the feed cost supposed to be reduced

when replacing the commercial SBM with a home-treated RFFSB. This cost reduction further pronounced in the remote areas where there is no soybean-oil extracting plants.

Significance Statement

By delivering an alternative feed ingredient to the stakeholders, it is expected that chicken production can be improved. But also, the production cost of the chicken industries can be reduced. Subsequently, the consumption of animal products by the society would be improved.

Abbreviations

AME = apparent metabolizeable energy; CP = crude proteins. AA= amino acids. ANFs = anti-nutritional factors; SBM = soybean meal; RFFSB= raw, full-fat soybean. BWT= body weight; BWTG = body weight gain; FCR = feed conversion ratio; FI = feed intake; WT= weight

Declarations

Ethics approval and consent to participate: **t**his current feeding trial has got ethics-approval and its reference number is stated in the materials and methods.

Consent for publication: **i**t is permitted to publish this manuscript in your journal.

Availability of data and material: data of this manuscript will be available when it will be required.

Competing interests: no potential conflict of interest.

Funding: no funding.

Authors' contributions: 1) Mammo Mengesha Erdaw, who has mainly planned and executed this feeding trial and also who drafted this manuscript and 2) Alemyahu Guteta, who helped in the data collection.

Acknowledgements: Authors' grateful credit and appreciation go to the Ethiopian Institute of Agricultural Research, specifically to the Debre-Zeit Agricultural Research Center for their nice facilitation.

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