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Research Article
Effects of Pelleting the Diets, Containing a Leveled Raw Full-Fat Soybean on the Performance of Broiler Chickens

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Abstract
Background and Objective: Searching for an alternative feed source was the objective of this study. Protein-source feedstuffs are mainly becoming costly and unavailable, therefore raw, full-fat soybean was considered an alternative source. Pelleting was considered to reduce antinutritional factors in raw soybean. **Materials and Methods:** A total of 408 unsexed broiler chicks were allocated to replicates. In a starter phase, commercial SBM was replaced by raw full-fat soybean (RFSB) at 0, 10 or 20%, which had three treatments and each was replicated eight times. Six treatments were prepared by dividing each of the aforementioned starter diets into two and then by pelleting anyone from each respective group and leaving the other as mash. Every treatment had four replicates and 17 birds in each. **Results:** Results indicated that FI, BWG and FCR of broilers were not significantly (p>0.05) affected by the supplementation of a levelled RFSB on diets at starter, grower and finisher phases. However, the interaction effect between the feed-form and levels of RFSB influenced (p<0.05) the FI, BW and BWG, at the grower stage. The FI, at the finisher stage, was also significantly (p<0.05) influenced by the feed-forms. Moreover, weights of dressed, eviscerated, cut parts of the carcass and visceral organs were not significantly (p>0.05) affected by both RFSB supplementations, up to 20% and the feed forms. **Conclusion:** It is concluded that commercial SBM can be replaced by locally produced RFSB at up to 20% without pelleting the diets.

Key words: Anti-nutrition, broiler chickens, pelleting, protein-source feeds, raw full-fat soybean, body-weight gains, meat characteristics

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Consumption of poultry meat and egg in Ethiopia is very low as compared to other countries. On the other hand, the demand for poultry products is generally increasing[1]. Globally, the broiler industry is immensely supplying animal proteins, but it is highly constrained by the availability, quality and cost of feed ingredients, regardless of the system of production in developing countries[2,3]. Feed is one of the factors which determine poultry, particularly broiler production and represents the major cost of production that constitutes up to 70% of the total[3,4]. Energy and crude protein intakes are generally essential in broiler production[2,5].

Soybean (*Glycine max* L.) is one of the leguminous plants and its byproducts called soybean meal (SBM) is the most important protein source used to feed the mono-gastric animals[6]. Soybean meal represents about 55% of the total global production of all oilseeds[7]. It is the by-product of the extraction of soybean oil which represents two-thirds of the total world output of protein feedstuffs[8,9]. Globally, soybean meal accounts for nearly 69% of all protein sources used in animal feeds[7] and dominates the market for protein supplements for poultry[5,7]. There are many reasons for this, including its consistency in nutrient content, its availability and its high content of crude protein[5]. In addition, it also contains substantially higher metabolizable energy content than other oilseed meals[4]. However, in addition to the quality, which is largely dependent on the processing technology and origins[5], commercial soybean meal is very expensive and inaccessible to small-scale producers.

In Ethiopia, 26 different soybean varieties are released with variable maturity and adaptability to different agro-ecologies[10]. The price of whole soybean grain, in the local market, is cheaper by 50% than that of the byproducts, for example, the commercial SBM. So far, there is no research conducted in the country on locally produced raw full-fat soybean grains as a feed ingredient used in the diets of chickens, particularly for broiler chickens. Locally produced RFSB grain was not yet tested, particularly when it is gradably included in diets and then found in its pelleted or non-pelleted forms.

Therefore, the objectives of this study were to assess the effects of replacing commercial soybean meal with a graded level of raw full-fat soybean, as a feed ingredient, in diets of broiler chickens and evaluate the effects of pelleting diets, containing graded levels of raw full-fat soybean on the performance of broilers.

MATERIALS AND METHODS

Study area: The study was conducted at Debrezeit Agricultural Research Center, Ethiopia. This study was undertaken in 2020/2021.

Study animals, husbandry practices and design: For this study, a total of 408, one-day-old, unsexed broiler chicks, with an average initial weight of 46.43±0.58 g, were purchased from a commercial hatchery farm, named ELFORA PLC. All birds were raised uniformly in 24-floor pens with teff straw was used as bedding material. An infrared bulb with 250 watts was used in each pen to generate electric heat. Brooding guards were also used in every pen. The temperatures of these pens were managed by controlling the height of the Infrared bulb. The space within the guards of the pens was 1.25 m by 1 m, which was sufficient that allowed the chicks to adjust themselves to that the intensity of heat, which was supposed to be generated by the bulb (s). Feed and water were provided *ad libitum* and the birds had free access to water. All vaccinations were given to birds as per the recommendations. The drinkers were washed on daily basis with clean water. The leftover feed was removed after being measured and the new diets were also offered to the birds on daily basis. Bio-security measures were applied. Birds were handled following standards Ethical Guidelines for the Use of Animals in Research[11].

The raw soybean seed, as a test feed ingredient was purchased from a local supplier in Addis Ababa. Before commencing the experiment chemical composition (Table 1) of feed ingredients was analyzed at both DZARC and Bless Agri. Food Laboratory Services PLC. Before mixing in diets, the raw soybean was cleaned and then hammer-milled to pass through a 2-mm sieve. Diets were formulated for starter, grower and finisher phases. Diet formulation has been conducted that tries to, at least satisfy the birds' minimum nutrient (major) requirements.

Table 2, this study had three parts, such as starter (0-14 d), grower (15-28 d) and finisher (29-49 d). Part one was undertaken, with a CRD design. Commercial soybean meal (SBM) was replaced by raw full-fat soybean (RFSB) at 0, 10 and 20% in starter diets. Eight replication per treatment was used, with 17 birds per replicate. After finishing the starter phase, which was 14 days, each of these three treatments was then subjected to divide into two. Anyone of this split-out, from each of the three treatments, was then pelleted and the other one was left as mash. The next two (grower and finisher)

Table 1: Nutritional composition of soybean meal, raw, and full-fat soybean

Feed ingredients	DM (%)	CF (%)	CP (%)	Ash (%)	Calcium
Bone and meat meal	95.78	3.54	46.87	32.64	7.8
Soybean meal	91.89	6.45	43.37	6.22	0.201
Raw soybean	92.36	15.73	33.04	5.11	-
Maize	89.7	2.53	8.69	2.72	0.182

Table 2: Treatment layout for starter, grower and finisher phases

	Phases of the experiment		
		After splitting and pelleting one diet	
Levels of RFSB, %	Starter phase	Grower phase	Finisher phase
0	T_1 (Control)	Non-pelleted	T_1
		Pelleted	T_2
10	T_2	Non-pelleted	T_3
		Pelleted	T_4
20	T_3	Non-pelleted	T_5
		Pelleted	T_6

Table 3: Ingredient composition of the experimental diets (g kg^{-1}) fed to starter (0-14 d), grower (14-28 d) and finisher (28-49 d) phases of broiler

	Starter			Grower			Finisher		
Ingredients	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Maize grains	580.5	590	582	608.5	614.5	617	629.5	629	631.5
Raw soybean	0	30	60	0	30	60	0	30	60
Food oil (un-saturated)	10	5	2.5	17.5	12.5	7.5	25	21.5	18
Soybean meal	300	270	240	300	270	240	300	270	240
Meat and bone meal	80	79.2	87.7	50	51.5	56	20	25	27.5
Limestone	8	8	8	6	6	6	4	4	4
Salt	3	3	3	3	3	3	3	3	3
DL-methionine	3	3	3	3	3	3	3	3	3
L-lysine	6	6	6	6	6	6	6	6	6
Premix	5	5	5	5	5	5	5	5	5
Dicalcium phosphate	4	4	4	4	4	4	4	4	4
Choline chloride	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

T_1: SBM was replaced by raw full-fat soybean at 0%, in diets, T_2: SBM was replaced by raw full-fat soybean at 10%, in diets and T_3: SBM was replaced by raw full-fat soybean at 20%, in diets

parts of this investigation were prepared, with a total of six treatments every treatment was then replicated 4 times and 17 birds each. Two forms of broiler diets (pelleted and non-pelleted) were used. All diets were formulated based on international recommendations. The diet was pelleted at GUTS Agro Industry PLC. The feed ingredient composition of each phase is described in Table 3. Every added feed to each pen was individually weighed. All birds were weighed as a group from the start to the end of the experiment in a regular one-week period.

Measurements and analytical methods: Immediately after arrival, the chicks were weighed in a group by the sensitive balance (which was considered as an initial weight) and then randomly assigned to the respective pens. All experimental birds were weekly weighed in a group during the experimental period. Bodyweight gain per bird for each pen was then computed using the following formula:

$$\text{Body weight gain (g)} = \frac{\text{Final body weight-initial body weight}}{\text{Number of birds}}$$

Feed intake: The measured amount of feed was offered at *ad libitum* throughout the experimental period. Feed refused from each pen was collected the next morning at 08:00 AM. The feed offered and refused were recorded for each pen. The amount of feed consumed was then determined as the difference between the feed offered and refused using the following formula:

$$\text{Feed intake}(\text{g / b}) = \frac{\text{Feed offered (g)} - \text{feed refused (g)}}{\text{Number of birds present}}$$

Feed conversion ratio (FCR) was determined by dividing the feed intake by body weight gain:

$$\text{Feed conversion ratio} = \frac{\text{Feed intake (g)}}{\text{Body weight gain (g)}}$$

Carcass yield and visceral organ measurements: At the end of the experiment two birds (one male and one female) per replicate were randomly selected. A total of 8 birds per treatment were humanly slaughtered. After bleeding, birds were placed in a scalding tank. The dressed weight (after legs, head and feather were removed) was then recorded.

Dressed carcass value was measured after the removal of blood, legs, head and feather and the dressing percentage was calculated as the proportion of dressed carcass weight to slaughter weight multiplied by 100.

After removal of the visceral organs, the eviscerated carcass weight was also recorded. The percentage value of eviscerated weight was then determined as the proportion of the eviscerated weight to slaughter weight multiplied by 100.

The main cutout weights/values of the carcass, such as breast, drumstick and thighs were recorded. The visceral organ weights (heart, liver, proventriculus and gizzard, duodenum and pancreas, small and large intestine) were also recorded.

Statistical analysis: All the collected data were arranged on Microsoft Excel 2010 before the actual data analysis was conducted. Descriptive statistics and one-way ANOVA were used to test the values of parameters, such as FI, BW, BWG and FCR on the starter phase as shown in Model 1. A general linear model (GLM) was used to analyse the main effects of the treatments on BWG, FI, FCR, carcass yield, cut part and visceral organ as shown in Model 2; using IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp (https://www.ibm.com/analytics/spss-statistics-software). The significant mean values, at p = 0.05, were separated by Duncan's Multiple Range Test (https://www.jstor.org/stable/3001478).

ANOVA Model 1: (FI, BW, BWG and FCR):

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where:

Y_{ij} = Observed j variable in the ith treatment
μ = Overall mean of the response variable
T_i = Effect due to the ith RFSB level (i = 0, 10, 20)
e_{ij} = Random residual error

ANOVA Model 2: (FI, BW, BWG FCR, Carcass yield, cut part and visceral organ):

$$Y_{ijk} = \mu + R_i + P_j + (R_i \times P_j)_k + e_{ijk}$$

Where:

Y_{ijk} = Observed k variable in the ith RFSB level and jth form of diet
μ = Overall mean of the observed variable
R_i = Effect due to ith RFSB level (i = 0, 10 and 20)
P_j = Effect due to jth form of diet (j = Pelleted and Non-Pelleted)
$R_i \times P_j$ = Effect due to the interaction between ith RFSB level and jth form of diet
e_{ijk} = Random residual error, significant differences were accepted if p<0.05.

RESULTS

Response of broilers fed graded levels of RFSB at starter phase: The results of the study on feed intake, body weight gain and feed conversion ratio of broiler chickens fed on diets, containing graded levels of RFSB at the starter phase are presented in Table 4. There was no significant (p>0.05) difference in FI of birds during the starter phase. Similarly, there was no significant (p>0.05) difference in BWG. There was no significant (p>0.05) difference between groups of birds in the FCR. However, it was observed that as the levels of RFSB increased from 0-10 or 20%, the FCR efficiency was reduced.

Response of broilers to feed-form and graded levels of raw soybean at grower phase: The gross response of birds (at the grower phase) fed on pelleted and non-pelleted diets, containing 0, 10 and 20% RFSB supplementations are presented in Table 5. Both the feed form and levels of RFSB did not significantly (p>0.05) affect the feed intake of birds. But the interaction effect on FI of birds between the feed-form and levels of RFSB had a significant (p<0.05) effect.

The body weight gain at the grower phase was not significantly (p>0.05) affected by the level of RFSB. However, birds fed on the non-pelleted and pelleted diets had a significant (p<0.05) difference in BWG. Moreover, the feed-form and levels of RFSB had significant (p<0.05) interaction effects on BWG. Birds that consumed 20% of the pelleted diet gained more bodyweight than the birds that consumed that of a 20% non-pelleted once. But, the birds that consumed the

Table 4: Feed intake (g/b), body weight gain ($g\ b^{-1}$), feed conversion ratio and body weight (g) of broiler chickens between the hatch and 14 days of age

					Body weight	
Feed form	RFSB (%)	Feed intake (1-14 days)	BWG (1-14 days)	FCR (1-14 days)	Initial	14 days
Mash	0	326.78	214.31	1.53	46.25	260.6
	10	333.99	213.23	1.57	46.25	259.62
	20	330.47	205.30	1.61	46.75	251.93
SEM		2.36	2.46	0.01	0.12	2.48
p-value		0.479	0.279	0.054	0.141	0.306

RFSB (%): Level of raw full-fat soybean (SBM was replaced by RFSB at 0, 10 and 20%, equivalent to 0, 30 and 60 $g\ kg^{-1}$ of diet, respectively), SEM: Pooled standard error of means, BWG: Body weight gain and FCR: Feed conversion ratio

Table 5: Feed intake ($g\ b^{-1}$), body weight gain ($g\ b^{-1}$), body weight (g) and feed conversion ratio of broiler chickens between the hatch and 28 days of age

Feed form	RFSB (%)	Feed intake (1-28 days)	Bodyweight gain (1-28 days)	FCR (1-28 days)	Body weights (28 days)
Pelleted	0	1121.34	566.73	2.0	612.88
	10	1207.74	655.98	1.84	702.04
	20	1259.53	712.642	1.77	759.14
Non-pelleted	0	1280.88	758.34	1.76	804.78
	10	1249.95	737.11	1.85	783.82
	20	1184.03	683.44	1.73	730.19
SEM		14. 6	6.47	0.02	6.52
Main effects					
RFSB (%)	0	1201.11	662.53	1.88	708.82
	10	1228.84	696.54	1.85	742.93
	20	1221.78	698.04	1.75	744.67
Feed form					
• Pelleted		1196.2	645.12^{b}	1.87^{b}	691.35^{b}
• Non pelleted		1238.29	726.3^{a}	1.78^{a}	772.93^{a}
Source of variation		p-value			
RFSB (%)		0.727	0.064	0.055	0.064
Feed form		0.167	0.000	0.046	0.000
RFSB×feed form		0.015	0.000	0.056	0.000

RFSB (%): Level of raw full-fat soybean (SBM was replaced by RFSB at 0, 10 and 20%, equivalent to 0, 30 and 60 $g\ kg^{-1}$ of diet, respectively), SEM: Pooled standard error of means, FCR: Feed conversion ratio, ^{ab}Indicates that columns with different superscripts are significantly different at p = 0.05 and Whilst computing the final BW and BWG, 16-17 unsexed birds were considered per replicate

non-pelleted diets, with 0% RFSB supplementation gained more weight than the pelleted ones.

The FCR value had also a significant (p<0.05) difference between birds fed pelleted and non-pelleted diets. Birds on the non-pelleted ones were more efficient than the others. But the FCR was not affected (p>0.05) by the level of RFSB and the interaction effects. The body weight of birds at the grower phase was not significantly affected (p>0.05) by the levels of RFSB. But the interaction effect between the feed-form and levels of RFSB was significant (p<0.05) on the BWG of birds. The birds that consumed the non-pelleted diets had a significant (p<0.05) difference in BWG as compared with the birds fed on the pelleted diets. Birds who consumed a 0% pelleted diet weighed less weight than the birds that consumed a 0% non-pelleted diet.

Response of broilers to the feed-form and supplements of raw soybean at finisher phase: The gross response of finisher birds fed on pelleted and non-pelleted diets, containing 0, 10 and 20% RFSB supplementation are presented in Table 6. In the finisher phase, the interaction effect between feed form and level of RFSB did not affect (p>0.05) the feed intake of birds. But the feed intake was significantly (p<0.05) affected by the feed form. The pelleted diet was consumed more than the non-pelleted feed.

Body weight gain, FCR and final BW, at the finisher phase, were not significantly affected (p>0.05) by both levels of RFSB and the feed-form. Moreover, BWG, FCR and final BW were not affected (p>0.05) by the interaction effects between the feed-form and level of RFSB.

Effects of feed-form and supplement of raw soybean on visceral organs development: Values of internal organ measurements of broilers fed on the pelleted and non-pelleted rations are presented in Table 7. According to the findings of the present study, there were no significant differences (p<0.05) found in the development of visceral organs, such as heart, liver, small and large intestine, gizzard

Table 6: Feed intake (g b^{-1}), body weight gain (g b^{-1}), body weight (g) and feed conversion ratio of broiler chickens between hatch and 49 days of age

Feed form	RFSB (%)	Feed intake (1-49 days)	Body weight gain (1-49 days)	FCR (1-49 days)	Body weights (49 days)
Pelleted	0	4745.27	2186.64	2.19	2232.77
	10	4711.75	2402.53	1.96	2448.59
	20	4595.32	2497.89	1.89	2544.39
Non-pelleted	0	4551.85	2376.31	1.89	2422.75
	10	4454.5	2289.37	1.95	2336.1
	20	4515.39	2390.67	1.91	2437.42
SEM		38.25	40.09	0.03	40.09
Main effects					
RFSB (%)	0	4648.56	2281.48	2.04	2327.76
	10	4583.13	2345.96	1.95	2392.35
	20	4555.36	2444.28	1.90	2490.90
Feed form					
• Pelleted		4684.11[a]	2362.35	2.02	2408.58
• Non-pelleted		4507.25[b]	2352.12	1.92	2398.76
Source of variation		p-value			
RFSB (%)		0.602	0.274	0.142	0.272
Feed form		0.033	0.900	0.086	0.904
RFSB×feed form		0.639	0.238	0.066	0.239

RFSB (%): Level of raw full-fat soybean (SBM was replaced by RFFSBM at 0, 10 and 20%, equivalent to 0, 30 and 60 g kg^{-1} of diet, respectively), SEM: Pooled standard error of means, FCR: Feed conversion ratio, [ab]Indicates that columns with different superscripts are significantly different at p = 0.05 and Whilst computing the final BW and BWG, 16-17 unsexed birds were considered per replicate

Table 7: Influence of diets, containing graded levels of raw full-fat soybean and feed-forms on development of internal organs (g/bird)

Feed form	RFSB (%)	Heart	Liver	S+L	G+P	P+D
Pelleted	0	11.50	52.75	66.50	88.25	25.00
	10	10.25	46.75	63.75	85.75	25.00
	20	11.50	52.75	63.25	83.50	24.50
Non-pelleted	0	10.25	47.25	65.50	83.25	27.00
	10	10.50	45.50	62.25	76.25	25.25
	20	10.00	51.25	55.50	80.25	24.50
SEM		0.299	1.494	2.228	2.018	0.650
Main effect						
RFSB level (%)	0	10.88	50.0	66.0	85.75	26.0
	10	10.38	46.13	63.0	81.0	25.13
	20	10.75	52.0	59.38	81.88	24.5
Feed form						
• Pelleted		11.08	50.75	64.5	85.83	24.83
• Non-pelleted		10.25	48.0	61.08	79.92	25.58
Source of variation		p-value				
RFSB (%)		0.779	0.289	0.492	0.601	0.646
Feed form		0.180	0.370	0.453	0.160	0.571
RFSB×feed form		0.449	0.811	0.791	0.810	0.794

RFSB (%): Level of raw full-fat soybean (SBM was replaced by RFSB at 0, 10 and 20%, equivalent to 0, 30 and 60 g kg^{-1} of diet, respectively), SEM: Pooled standard error of means, G+P: Gizzard+Proventriculus, P+D: Pancreas+Duodenum, S+L: Small+Large Intestines, Two (one male and one female) per replicate and a total of eight birds per treatment were randomly selected and scarified in testing the effects of test diets on internal organ developments and Digesta content was not emptied from intestines, gizzard or duodenum

and proventriculus, pancreases and duodenum of broiler fed on diets, containing graded levels (0, 10 and 20%) of RFSB. These organs were not either affected by pelleted or non-pelleted diets too.

Effects of feed form and supplement of raw soybean on carcass characteristics: The carcass characteristics of broilers, fed on pelleted and non-pelleted diets, containing graded levels of RFSB are presented in Table 8. There was no significant (p>0.05) difference in the slaughter, dressed, eviscerated weights and weights of carcass cuts (drumsticks, thighs and breasts) of birds fed on pelleted and non-pelleted diets, containing 0, 10 and 20% of RFSB.

Mortality and culling: Only 4 birds died and the other 10 birds were also purposely culled during entire experimental periods,

Table 8: Influence of diets, containing graded levels of raw full-fat soybean and feed forms on carcass yield and cut parts (g/bird)

Feed form	RFSB (%)	BW/bird	Dressed (%)	Eviscerated (%)	Drumstick	Thigh	Breast
Pelleted	0	2192.50	86	70.25	213.50	238.50	498.00
	10	2214.50	88	73.75	207.50	289.25	490.25
	20	2271.25	88.3	75.25	214.00	271.75	504.00
Non-pelleted	0	2070.25	91.5	74.75	202.25	253.50	473.75
	10	2160.00	87.3	74.25	200.50	254.00	490.50
	20	2038.00	89.3	75.25	204.25	248.00	467.00
SEM		57.6	44.13	42.05	5.78	8.22	11.05
Main effects							
RFSB level (%)	0	2131.38	88.75	72.5	207.88	246.0	485.88
	10	2187.25	87.63	74	204.0	271.63	490.38
	20	2154.63	88.75	75.25	209.13	259.88	485.5
Feed form							
• Pelleted		2226.08	87.42	73.08	211.67	266.5	497.42
• Non-pelleted		2089.42	89.33	74.75	202.33	251.83	477.08
Source of variation		p-value					
RFSB (%)		0.924	0.971	0.730	0.932	0.460	0.980
Feed form		0.251	0.325	0.384	0.430	0.384	0.370
RFSB×feed form		0.817	0.669	0.621	0.988	0.442	0.786

RFSB (%) : Level of Raw full-fat soybean (SBM was replaced by RFSB at 0, 10 and 20%, equivalent to 0, 30 and 60 g kg^{-1} of diet, respectively), SEM: Pooled standard error of means, BW: Body weight and two (one male and one female) per replicate and a total of eight birds per treatment were randomly selected and scarified in testing the effects of test diets on the carcass characteristics

which was a totally of 3.4%. The 10 birds were culled due to severe leg weakness. Apart from the birds culled or found dead, no health problems were observed.

DISCUSSION

There was no significant difference in the FI, BWG, BW and FCR of birds fed diets, containing a levelled RFSB supplementation at the starter phase. This current result is in agreement with Erdaw *et al.*[12], who reported that broilers aged from day 1-10 that consumed up to 20% (60 g kg^{-1}) showed no significant difference in FI, but the same authors reported also that when RFSB was increased to 75 g kg^{-1}, the BWG and feed efficiency were reduced. Rada *et al.*[13] reported also that broilers fed on RFSB up to 4, 8 and 12%, which are equivalent to 40, 80 and 120 g kg^{-1} up to 10 days of age had no significant influence on BWT. Though it was not statistically significant in the current study, similar trends were observed in feed efficiency and BWT as the level of RFSB increases from 10-20% in diets. This result agrees with the reports of other scholars[12,14]. The depressed performance observed for broiler chicks suggests that younger birds are more susceptible to the effects of trypsin inhibitors[14].

The FI, BWG, FCR and BW were not affected by an increased level of RFSB in the diets. This is contrary to Perez-Maldonado *et al.*[14], who reported that as RFSB increases to 12% the BWT is reduced. These current results are in agreement with Erdaw *et al.*[12], who reported that increasing the level of RFSB in diets did not affect FI, BWG and FCR, during 1-28 d of age. Similar findings were also reported by other scholars[13,15].

However, the feed-form significantly influenced the BWG, BW and FCR of this current study that was birds fed on non-pelleted diets were superior to those on pelleted ones. In most cases, the birds that fed on a pelleted diet gained superior body weight and improved feed efficiency[16]. But the variation in this finding might be happened due to a non-gradual shifting of birds from mash-form of diets to pelleted ones which might contribute to the reduced FI. In addition, it might be due to the poor quality of the pelleted diets[16-19]. This is also supported by Sibanda and Ruhnke[20], who reported that the nutritional quality of pellets can be significantly influenced by the duration and temperature of heat exposure. Abdollahi *et al.*[21] also reported that due to the heat, moisture and mechanical pressure applied during conditioning and pelleting, some chemical and physical alterations occur that may have beneficial or detrimental effects on feed components, gastrointestinal development and subsequent bird performance. Similarly, under-processing or over-heating influenced broiler performances[15].

The FI, BWG and BW were influenced, in the grower stage by the interaction effects between the feed form and level of RFSB supplementation. But this current result disagrees, with Erdaw *et al.*[19], who reported that there was no interaction effect between RFSB and pelleting methods, on the FI, BWG, or FCR of birds for 14 days of age. Birds in pelleted diets, containing 20% RFSB had higher FI and BWG than those on non-pelleted diets. This current result agrees with

Abdollahi *et al.*[21], who reported that there might be incomplete inactivation of anti-nutritional factors, insufficient starch gelatinization and inadequate protein denaturation, whilst over-processing can result in the formation of Maillard reaction products and inactivation of supplemental enzymes and vitamins.

The FI at the finisher stage was influenced by the fed-form. Birds that fed the pelleted diet consumed more than those on the non-pelleted. This result might be supported by Lilly *et al.*[17] and Chehraghi *et al.*[22], who reported that the highest FI was observed in birds fed on pelleted diets and the lowest FI was observed in the crumble and mash group. Improved feed efficiency and better performance can often be observed when feeding processed diets compared to the mash form[21]. Abdollahi *et al.*[21] added also that pelleted diets contribute to enhancing the economics of production by increasing the FI and thus growth performance and feed efficiency. In line with this, Erdaw *et al.*[19] reported also that birds consumed more amounts of non-steam-pelleted diets and gained more weight than birds fed on steam-pelleted ones of the same diets. However, BWG, FCR and BW at the finisher phase of the current study were not significantly affected by the level of RFSB supplementations and the feed-form. In agreement with this, scholars[12,16,19,20] had similar reports on the effects of feed-forms. In agreement with the current finding, Rada *et al.*[13] reported that RFSB up to 8% (80 g kg^{-1}) could be used in the broiler diets without having a significantly negative effect on the growth rate and FCR. Similarly, Erdaw *et al.*[23] suggested that commercial SBM could be replaced by RFSB up to 25% (75 g kg^{-1}) in broiler diets with microbial protease and phytase supplementation. The study showed that growth rate and FCR were negatively influenced when 12% (120 g kg^{-1}) of RFSB were included in the diet[13].

There was no significant difference in the slaughter, dressed, eviscerated weights and weight of carcass cuts, including drumstick, thighs and breasts of birds fed on pelleted and non-pelleted diets, containing 0, 10 and 20% RFSB supplementation. In agreement with Al-Sardary[15], who reported that broilers fed up to 20% (200 g kg^{-1}) RFSB supplementation had no significant difference observed in live body weight, thigh and breasts. Similarly, Erdaw *et al.*[12] reported that up to 20% RFSB supplementation had no significant difference in dressed percentage, drumstick, thighs and breasts. Rocha *et al.*[24] reported also that up to 15% RFFSB (equivalent of 150 g kg^{-1} diet) supplementation did not affect the live weight of birds.

In this current study, there was no significant difference in the development of visceral organs such as heart, liver, small and large intestine, gizzard and proventriculus, pancreases and duodenum of broilers fed on pelleted or non-pelleted diets, containing graded levels of RFSB supplementation. There were no significant differences in the weights of heart, gizzard and liver were observed on broilers fed on pelleted or mash diets[19]. Though not statistically significant, broilers fed on non-pelleted diets with RFSB showed heavier weights of pancreases and duodenum than those on the pelleted ones. In agreement with this current finding, Rocha *et al.*[24] reported also that broilers fed on diets, containing up to 15% (the equivalent of 150 g kg^{-1}) RFSB had heavier pancreas weight at 21 days of age. Similarly, Erdaw *et al.*[19,25] reported that increasing the levels of RFSB supplementations, in diets, increased the weights of the pancreas (10, 24 and 35 days). Rada *et al.*[13] also confirmed that broiler fed 4, 8 and 12% RFSB showed heavier pancreases weight.

The implication of this study is to improve chicken meat production by reducing feed costs. The price of raw soybean, around the study areas, is cheaper than that of the commercial SBM. Therefore, when formulating diets for their chickens, producers are advised to replace the commercial SBM with raw, full-fat soybean, up to 20%.

CONCLUSION

Broiler chickens fed on diets, containing 0, 10 and 20% RFSB supplementation did not affect FI, BWG, BW, FCR, during the starter and grower phases. However, the BWG and FI were affected by the interaction effects of feed-form and by a graded level of RFSB supplementations on diets, at the grower phase. The birds that consumed a diet containing 20% RFSB in the form of a pelleted diet had higher FI and BWG than the non-pelleted ones. The FCR had also a significant difference between birds fed pelleted and non-pelleted diets. The FI, at the finisher phase, was influenced by the fed-form. However, BWG and FCR were not significantly affected by either level of RFSB or the feed-form. The dress, eviscerated, carcass-cuts and weights of visceral organ developments were not affected by the inclusion of a levelled RFSB as well as the feed-forms. In general, it is possible to replace the commercial SBM with locally produced RFSB, up to 20% without the need to pelleting the diet.

SIGNIFICANCE STATEMENT

This study confirmed that, without compromising any production parameter, the raw, full-fat soybean can substitute that of the commercial SBM, up to 20% for broiler chickens. These findings from the current study will serve producers boost production by reducing the feed cost. This is a discovery that although commercial SBM was replaced (up to 20%) by the raw full-fat soybean, the anti-nutritional factors that were supposed to be found in the raw soybeans, were not powerful enough to influence the performance of broiler chickens.

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