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Effect of various levels of processed full-fat soybean on growth performance, nutrients digestibility, gut morphometry and serum biochemistry in broiler chickens

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The study was conducted to evaluate the effect of extruded full-fat soybean and toasted full-fat soybean on nutritive value and growth performance in broiler chickens. A 2×5 experiment using 2 processing conditions and five inclusion levels (0, 5, 10, 15 and 20%) of full-fat soybean were under-taken applying factorial arrangement under completely randomized design. One day old broiler chicks (n=480) were pre-cured from commercial hatchery and divided into forty (40) replicates having 12 chicks/replicate. Ten iso-nitrogenous and iso-caloric starter (ME kcal/kg: 3000, CP: 23 %), grower (ME kcal/kg: 3100, CP: 21.5 %) and finisher (ME kcal/kg: 3200, CP: 20 %) experimental diets were formulated. Diets A-E contained extruded full-fat soybean, while diets F-J contained toasted full-fat soybean at 0, 5, 10, 15 and 20 %, respectively. The biological trial lasted for 32 days. The results of study demonstrated that feed intake, body weight gain and FCR were not affected *(P>0.05)* with the inclusion of extruded full-fat soybean and toasted full-fat soybean. It was inferred that extruded full-fat soybean and toasted full-fat soybean could be included in broiler diets without affecting the growth performance in broiler chickens. Full-fat soybean contained around 36% CP, 22.5% EE, 3.29% crude fiber, 5.23% ash and 89% dry matter. Growth of the birds remain unaffected *(P>0.05)* with the dietary inclusion of full-fat soybean in the broiler diets. No effect was noted on overall growth performance with the increasing levels of extruded or toasted full-fat soybean in diets. Digestibility of CP and EE remained the same at 11^{th}, 21^{st} and 32^{nd} day of trial. Apparent metabolisable energy, Nret and AMEn were also similar *(P>0.05)* for all dietary treatments across the treatments. The birds showed similar hematology and serum biochemistry. It was concluded that extruded or toasted full-fat soybean could effectively replace soybean meal up to 20% in broiler rations without having adverse effect on growth, nutrients digestibility and gut morphometry.

Keywords: Extruded full-fat soybean, toasted full-fat soybean, broiler chickens

INTRODUCTION

Soybean seeds (glycine max) contain about 36-40 % protein and 18-22% oil. The soybean protein is an excellent blend of essential amino acids, making it an outstanding source of protein source with balanced amino acid profile for diets of poultry and other classes of livestock (Newkirk, 2008). Soybean meal accounts for more than 50% of world protein meals. Import of soybean is in Pakistan 2.5 million ton close to the production of largest local oilseed commodity cottonseed, which was 3.3 million ton in 2017/18. Of the soybean seeds imported in Pakistan, over 99% is utilized in livestock feeding. The soybean seeds are either subjected to solvent extraction process for extraction of oil and production of soybean meal or used as such as full fat soybean (Van Eys, 2012). In general, full-fat soybean is not only a good source of protein but also of dietary energy due to high oil contents and therefore they can replace soybean meal (SBM) and oil in poultry diets with similar anticipated performance (Subuh et al. 2002). Protease inhibitor is main anti nutritional factors in the soybeans which affect the broiler performance. Growth depression, observed when trypsin inhibitors are ingested (Erdaw et al. 2016), that may be due to combined effect of endogenous loss of essential amino acids (EAA) and decreased in intestinal proteolysis. Trypsin inhibitor and urease activity (UA) is correlated to body weight and feed conversion ratio (Rada et al. 2017). Major anti-nutritional factor is trypsin inhibitor can be destroyed through various heat procedures like extrusion and toasting. Optimal heating is required to get maximum protein quality with highest degree of inactivation of anti-nutritional factors present in full-fat soybean (Ari et al. 2017). Quality off soy products can be determined using various analytical techniques like potassium hydroxide (KOH) solubility, pepsin digestibility, protein dispensability index (PDI), available lysine, acid detergent insoluble nitrogen (NDIN) etc. These in-vitro techniques provide efficient and very close observations of protein digestibility determined employing in vivo techniques. The objective of various processing techniques is to keep the quality of protein integrated in terms of digestible amino acids contents with the maximum degradation of anti-nutritional factors (Van Eys, 2012).

Possibility of utilization processed full-fat soybean (FFS) in replacement for both soybean meal and oil in chicken diets, has been studied (Ruiz et al. 2004; Rasool, 2017). Extrusion and toasting are ways of heat treatments to eliminate anti-nutritional effects and to improve nutritional value of soybean (Ruiz et al. 2004; Clarke and Wiseman, 2007; Foltyn et al. 2013). Hamilton and McNiven (2000) reported improved body weight gain was improved with diets having processed full-fat soybeans as compared to birds fed soybean meal-based diets. Previous studies have highlighted the sensitivity of broiler chickens to the variation of trypsin inhibitors in full-fat soybean (Clarke and Wiseman, 2007). Changes in processing conditions were the most likely reasons for this variability and there was a need to examine the consequences of alterations in the processing conditions on subsequent nutritional value. This would allow the identification of those conditions leading to optimum nutritional quality. Toasted full-fat soybean high temperature (90-110ºC) for a longer period of time (30 – 60 mins). A high temperature treatment of full-fat soybean during toasting provides an ideal condition for Maillard reaction that affects nutritive value of meal especially in terms of amino acid availability (Anderson-Hafermann et al. 1993). Woyengo et al. (2010) reported higher digestible amino acid contents for untoasted meal than toasted. While during extrusion process full-fat soybean is exposed to very high temperature (145-165ºC) for very short duration (15-25 s) of time. The extrusion cooking is also reported to have an enhancing effect on digestibility of starch and protein through gelatinization and breaking the tertiary structures of protein, respectively. Thus, it is critical to determine the nutritive value of full-fat soybean produced by different processing techniques *i.e.* toasting and extrusion.

This study was planned to determine the effect of various processing conditions of full-fat soybean on nutritive value, growth performance, nutrients digestibility and gut morphology in broiler chickens.

MATERIALS AND METHODS

All procedures followed to conduct this experiment were approved by Advanced Studies and Research Board (ASRB), University of Agriculture, Faisalabad, Pakistan.

Preparation of full-fat soybean

Solvent extracted soybean meal

Solvent extracted soybean meal (SBM) was prepared through solvent extraction process at Hi-tech Edible Oil Mills (Pvt.) Limited, Sahiwal. The solvent extraction process includes seeds cleaning, de-hulling, flanking, conditioning, expeller extraction, solvent extraction and desolventization/toasting process. The meal obtained after solvent extraction process had less than 1% EE and approx.45% CP.

Toasted full-fat soybean

Toasted full-fat soybean was also prepared at Hi-Tech Edible Oil Mills (Pvt.) Limited, Sahiwal using multi desk toaster/conditioner provided with jacketed and open steam. Soybean seeds were cleaned, de-hulled and flaked to the thickness of 0.3-0.38 mm before subjecting to toasting at 90 °C for 45 minutes. Toasted full-fat soybean contained up to 22% EE and 37% CP contents.

Extruded full-fat soybean

Extruded full-fat soybean was prepared at Hoor Oil Mills (Pvt.) Limited, Multan. The soybean seads were cleaned, dehulled and extruded at 145 °C for 15-20 seconds.

Chemical analysis

The meals prepared for experiment were analyzed for proximate composition (AOAC, 2010), urease activity (∆pH), pepsin digestibility and KOH solubility (Araba and Dale, 1990) were also assayed prior to inclusion of the meal in diets.

Experimental diets, birds and housing

In this experiment, soybean meal was replaced with extruded full-fat soybean and toasted full-fat soybean at five dietary levels i.e. 0, 5, 10, 15 and 20%. For this purpose, ten iso-nitrogenous and iso-caloric starter (CP 23%; ME 3000 Kcal/ Kg), grower (CP 21.5%; ME 3100 Kcal/ Kg) and finisher (CP 19.5%; ME 3200 Kcal/ Kg) diets were formulated following nutritional recommendations provided by Ross-308 broiler chicken manual. Diets A-E contained extruded full fat soybean, while diets F-J contained toasted full fat soybean at 0, 5, 10, 15 and 20%, respectively. The experimental diets were be fed to four hundred and eighty (n=480) broiler chicks procured for commercial hatchery and randomly divided into forty treatment groups with four replicates having twelve birds each replicate. Ingredients and nutrients composition of the diets is given in Tables 2-4. The flock was reared on a concrete floor covered with 2-inch layer of saw dust as bedding material. Each bird was allotted a floor space of 0.074 m^2 in a 3×4 square feet pen in a controlled shed. The birds were vaccinated according to the local vaccination schedule. In brief, the birds were vaccinated against infectious bronchitis (IB) on day 3rd, infectious bursal disease (IBD) on day 12th followed by Newcastle disease (ND) on day 17th and 28th day of the trial. Each pen was provided with a round bottom feeder while water supply was made available round the clock through nipple drinking system. The room temperature was maintained at 32°C during first week of the trial with subsequent reduction of 3°C every week. Provision of uninterrupted light round the clock was ensured during experimental period.

Nutrient Digestibility assay:

On day 10^{th}, 21^{st} and 35^{th} of the trial, a digestibility trial was carried out. Acid Insoluble ash (Celite®) was added @ 1% in starter grower and finisher diets, which were fed to experimental birds. This scheme of feeding continued till the termination of the trial. On day 9th, 19^{th} and 32^{nd} day polythene sheets were spread replicate wise and droppings was collected after every 3 hours on day 11^{th}, 21^{st} and 35^{th}. The collected samples were then transferred to plastic cups and kept immediately into an ice container to freeze them at -10°C. These fecal samples within the pen were pooled and then oven dried in a hot air oven at 65°C and ground to pass through sieve (0.5 mm). These were then kept at -10°C till further analyses. Diets were analysed for DM, N, CP, EE, crude fiber, ash and gross energy (GE). Digesta samples were analysed for N by micro Kjeldahl apparatus, AIA (Vogtmann et al. 1975) and GE by Parr oxygen bomb calorimeter (Parr Instrument Co. Moline, IL).

The digestibility of nutrients was measured by following formula:

$$Digestibility\ (\%) = 100 - (100x\frac{\%AIA_{feed}}{\%AIA_{feces}}x\frac{\%AIA_{feces}}{\%AIA_{feed}})$$

The AME values of the diets were calculated by the following formula:

$$AME_{(kcal/kg)} = GE_{diet} - \left[GE_{feces} \times \left\{\frac{AIA_{diet}}{AIA_{feces}}\right\}\right]$$

The catabolic compound in excreted N leads to considerable energy loss. Therefore, AME was adjusted to zero N retention employing a factor of 8.22 kcal/g (Hill and Anderson, 1958) so as AME_n = AME- (8.22 × N_{ret}), where N_{ret} is nitrogen retention in g/kg DM intake. The N_{ret} was calculated as per the formula stated by Bolarinwa and Adeola (2012):

$$N_{ret} = N_{diet} - \left(N_{digesta} \times \frac{AIA_{diet}}{AIA_{digesta}}\right)$$

Growth performance

Body weight gain of the birds was recorded on arrival and thereafter at the end of each phase. Digital weighing balance was used for weighing the birds. Feed intake was calculated by subtracting the amount of the feed refused from the total quantity of feed offered during whole phase. Feed intake was calculated using the following formula:

$$\text{Feed intake} = \text{Feed offered} - \text{Feed refused}$$

Feed conversion ratio (feed: gain) was calculated for each week using the following relationship:

$$\text{FCR} = \frac{\text{Feed intake in grams}}{\text{Weight gain in grams}}$$

Gut Morphometry

On day 35^{th} a section of about 5cm from the middle of small intestine was excised from slaughtered bird and fixed with neutral buffered formaldehyde and then stored in 70% alcohol. Preserved samples were prepared and mounted on slides. Mounted samples will be stained with Hematoxylin and Eosin (H&E). J-image software was used to determine the villus length and crypt depth (Bancroft et al. 2018).

Hematology

At the end of experiment blood samples (one sample/replicate) was collected in ethylene di-amine tetra acetic acid (EDTA) vial using 5 cc syringe from jugular vein and analyzed by using automatic Hematology Analyzer (Hemalyzer-203D Plus, Germany).

Statistical analysis:

Data were analyzed statistically using the generalized linear model (GLM) procedures of Minitab 17.1 (Minitab Inc., State College, PA). The experiment was 2×5 factorial experiment applied to completely randomized design. Means were separated by Tukey's honestly significant difference test (Steel et al. 1997).

Table 1: Proximate composition and quality parameter of soybean

Nutrients, %	Full-fat Soybean		Solvent extracted SBM	Reference
	Extruded	Toasted		
Dry matter	90.8	92.45	90.47	AOAC (2010)
Crude Protein	36.75	35.95	45.94	AOAC (2010)
Fat	18.5	21.5	1.01	AOAC (2010)
Crude Fiber	5.35	3.56	5.47	AOAC (2010)
Ash	5.67	5.79	5.76	AOAC (2010)
KOH Solubility	79.9	81.3	80.2	Araba and Dale (1990)
∆pH	0.02	0.02	0.01	AOCS (2011)
Pepsin Digestibility	76.7	79.9	81.1	Bellaver et al. (2000)

Table 2: Ingredient and nutrient composition of starter diets (1-10 days)

Ingredients	Extruded full-fat soybean (135°C, 15-20 s)					Toasted full-fat soybean (90°C, 45 min)				
	A (0%)	B (5%)	C (10%)	D (15%)	E (20%)	F (0%)	G (5%)	H (10%)	I (15%)	J (20%)
Maize	51.07	50.89	50.69	50.35	50	51.07	51	50.89	50.69	50.62
Extruded full-fat soybean	**0**	**5**	**10**	**15**	**20**	**-**	**-**	**-**	**-**	**-**
Toasted full-fat soybean	**-**	**-**	**-**	**-**	**-**	**0**	**5**	**10**	**15**	**20**
Soybean meal	39.81	35.82	31.85	28	24.19	39.81	35.84	31.85	28	24
Soybean oil	3.8	2.95	2.1	1.28	0.46	3.8	2.83	1.9	0.94	0
Calcium carbonate	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
di-Calcium phosphate	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Sodium chloride	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Sodium bicarbonate	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Lysine sulphate, 55%	0.32	0.33	0.34	0.34	0.35	0.32	0.33	0.34	0.34	0.35
DL- Methionine, 99.5 %	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
L-Threonine, 99%	0.12	0.12	0.13	0.13	0.13	0.12	0.12	0.13	0.13	0.13
L-Isoleucine, 99%	0	0	0	0	0	0	0	0	0	0
L-Valine, 99%	0.02	0.03	0.03	0.04	0.04	0.02	0.03	0.03	0.04	0.04
Vitalink®[a]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nutrimin®[b]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Choline Chloride, 70%	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Celite® (AIA)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nutrients (%)										
ME (Kcal/kg)	3000	3000	3001	2999	3000	3000	3000	3000	3000	3000
CP	23	23	23	23	23	23	23	23	23	23
EE	6.41	6.50	6.63	6.85	6.85	6.41	6.40	6.56	6.92	6.92
CF	3.24	3.30	3.36	3.50	3.50	3.24	3.30	3.36	3.48	3.48
Ca	0.99	0.99	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Av. P	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Na	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Cl	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Dig. Lys	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Dig. Met	0.65	0.65	0.65	0.64	0.64	0.65	0.65	0.65	0.64	0.64
Dig. M + C	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Dig. Thr	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Dig. Trp	0.26	0.26	0.25	0.25	0.25	0.26	0.26	0.25	0.25	0.25
Dig. Arg	1.42	1.41	1.41	1.40	1.40	1.42	1.41	1.41	1.40	1.40
Dig. Ile	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Dig. Val	0.96	0.97	0.96	0.97	0.96	0.96	0.96	0.96	0.97	0.96
Dig. Leu	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41

[a]Each kg of vitalink® supplied the following: Vitamin A, 20000 KIU; Vitamin D_3, 5400 KIU; Vitamin E, 48000 mg; Vitamin K_3, 4000 mg; Vitamin B_1, 4000 mg; Vitamin B_2, 9000 mg; vitamin B_6, 7600 mg; vitamin B_{12}, 20 mg; niacin, 60000 mg; pantothenic acid, 20000 mg; folic acid, 1600 mg; biotin, 200 mg).
[b]Each kg of nutrimin® supplied the following: iron, 10000 mg; zinc, 120000 mg; manganese, 140000 mg; copper, 12000 mg; iodine, 1800 mg; cobalt, 400 mg; and selenium, 360 mg

Table 3: Ingredient and nutrient composition of grower diets (11-21 days)

Ingredients	Extruded full-fat soybean (135°C, 15-20 s)					Toasted full-fat soybean (90°C, 45 min)				
	A (0%)	**B (5%)**	**C (10%)**	**D (15%)**	**E (20%)**	**F (0%)**	**G (5%)**	**H (10%)**	**I (15%)**	**J (20%)**
Maize	54.01	53.73	53.45	53.28	52.87	54.01	54.83	54.66	54.6	54.55
Extruded full-fat soybean	**0**	**5**	**10**	**15**	**20**	**-**	**-**	**-**	**-**	**-**
Toasted full-fat soybean	**-**	**-**	**-**	**-**	**-**	**0**	**5**	**10**	**15**	**20**
Soybean meal	36.3	32.4	28.5	24.5	20.7	36.3	32.4	28.5	24.5	20.5
Soybean oil	4.84	4.01	3.18	2.33	1.5	4.84	3.9	2.96	2	1.03
Calcium carbonate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
di-Calcium phosphate	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65
Sodium chloride	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Sodium bicarbonate	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Lysine sulphate, 55%	0.21	0.22	0.23	0.25	0.25	0.21	0.22	0.23	0.25	0.25
DL- Methionine, 99.5 %	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
L-Threonine, 99%	0.08	0.08	0.08	0.08	0.09	0.08	0.08	0.08	0.08	0.09
L-Isoleucine, 99%	0	0	0	0	0	0	0	0	0	0
L-Valine, 99%	0	0	0	0	0.01	0	0	0	0	0.01
Vitalink®[a]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nutrimin®[b]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Choline Chloride, 70%	0.06	0.06	0.06	0.06	0.06	0.06	0.005	0.005	0.005	0.005
Celite® (AIA)	1.00	1.00	1.00	1.00	1.00	1.00	0.06	0.06	0.06	0.06
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nutrients (%)										
ME (Kcal/kg)	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100
CP	21	21	22	22	21	21	22	22	21	22
EE	7.50	7.62	7.74	7.84	7.93	7.50	7.51	7.67	7.83	8.00
CF	3.14	3.21	3.27	3.34	3.50	3.14	3.21	3.27	3.33	3.48
Ca	0.91	0.91	0.91	0.90	0.90	0.91	0.87	0.87	0.87	0.87
Av. P	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Na	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Cl	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Dig. Lys	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Dig. Met	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Dig. M + C	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Dig. Thr	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.78
Dig. Trp	0.24	0.24	0.24	0.23	0.23	0.24	0.24	0.24	0.23	0.23
Dig. Arg	1.32	1.31	1.31	1.30	1.30	1.32	1.31	1.31	1.30	1.30
Dig. Ile	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
Dig. Val	0.88	0.88	0.87	0.87	0.87	0.88	0.88	0.87	0.87	0.87
Dig. Leu	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27

[a]Each kg of vitalink® supplied the following: Vitamin A, 20000 KIU; Vitamin D_3, 5400 KIU; Vitamin E, 48000 mg; Vitamin K_3, 4000 mg; Vitamin B_1, 4000 mg; Vitamin B_2, 9000 mg; vitamin B_6, 7600 mg; vitamin B_{12}, 20 mg; niacin, 60000 mg; pantothenic acid, 20000 mg; folic acid, 1600 mg; biotin, 200 mg).

[b]Each kg of nutrimin® supplied the following: iron, 10000 mg; zinc, 120000 mg; manganese, 140000 mg; copper, 12000 mg; iodine, 1800 mg; cobalt, 400 mg; and selenium, 360 mg

Table 4: Ingredient and nutrient composition of finisher diets (21-35 days)

Ingredients	Extruded full-fat soybean (135°C, 15-20 s)					Toasted full-fat soybean (90°C, 45 min)				
	A (0%)	B (5%)	C (10%)	D (15%)	E (20%)	F (0%)	G (5%)	H (10%)	I (15%)	J (20%)
Maize	58.26	58.14	57.85	57.58	57.25	58.26	58.29	58.34	58.08	58.23
Extruded full-fat soybean	0	5	10	15	20	-	-	-	-	-
Toasted full-fat soybean	-	-	-	-	-	0	5	10	15	20
Soybean meal	31.2	27.2	23.3	19.4	15.6	31.2	27.2	23.15	19.4	15.3
Soybean oil	5.71	4.83	4	3.2	2.3	5.71	4.68	3.65	2.7	1.6
Calcium carbonate	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
di-Calcium phosphate	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Sodium chloride	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Sodium bicarbonate	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Lysine sulphate, 55%	0.22	0.22	0.24	0.25	0.24	0.22	0.22	0.25	0.25	0.26
DL- Methionine, 99.5 %	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.27
L-Threonine, 99%	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
L-Isoleucine, 99%	0	0	0	0	0	0	0	0	0	0
L-Valine, 99%	0	0	0	0	0	0	0	0	0	0
Vitalink®[a]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nutrimin®[b]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Choline Chloride, 70%	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Celite® (AIA)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	100	100	100	100	100	100	100	100	100	100
Nutrients (%)										
ME (Kcal/kg)	3200	3200	3201	3200	3200	3200	3200	3200	3200	3200
CP	20	19	19	20	19	20	20	20	20	20
EE	8.44	8.48	8.52	8.58	8.60	8.44	8.57	8.71	8.88	9.05
CF	3.00	3.06	3.13	3.20	3.26	3.00	3.10	3.16	3.22	3.28
Ca	0.87	0.87	0.87	0.87	0.87	0.87	0.80	0.80	0.80	0.79
Av. P	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Na	0.19	0.19	0.19	0.19	0.19	0.19	0.16	0.16	0.16	0.16
Cl	0.22	0.22	0.22	0.22	0.22	0.22	0.20	0.20	0.20	0.20
Dig. Lys	1.03	1.03	1.03	1.03	1.03	1.03	1.05	1.05	1.05	1.05
Dig. Met	0.54	0.54	0.54	0.54	0.53	0.54	0.56	0.55	0.55	0.54
Dig. M + C	0.80	0.80	0.80	0.81	0.79	0.80	0.82	0.82	0.82	0.82
Dig. Thr	0.70	0.69	0.69	0.69	0.69	0.70	0.70	0.71	0.70	0.70
Dig. Trp	0.21	0.21	0.21	0.21	0.20	0.21	0.22	0.22	0.21	0.21
Dig. Arg	1.17	1.17	1.16	1.16	1.15	1.17	1.20	1.20	1.19	1.19
Dig. Ile	0.73	0.72	0.72	0.72	0.72	0.73	0.75	0.74	0.74	0.74
Dig. Val	0.79	0.79	0.78	0.78	0.77	0.79	0.81	0.81	0.80	0.80
Dig. Leu	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13

[a]Each kg of vitalink® supplied the following: Vitamin A, 20000 KIU; Vitamin D_3, 5400 KIU; Vitamin E, 48000 mg; Vitamin K_3, 4000 mg; Vitamin B_1, 4000 mg; Vitamin B_2, 9000 mg; vitamin B_6, 7600 mg; vitamin B_{12}, 20 mg; niacin, 60000 mg; pantothenic acid, 20000 mg; folic acid, 1600 mg; biotin, 200 mg).

[b]Each kg of nutrimin® supplied the following: iron, 10000 mg; zinc, 120000 mg; manganese, 140000 mg; copper, 12000 mg; iodine, 1800 mg; cobalt, 400 mg; and selenium, 360 mg

RESULTS AND DISCUSSION

Proximate composition/ amino acid composition of SBM and full-fat soybean is given in Table 1. Full-fat soybean (SB) was either extruded or toasted. Extruded full-fat SB, toasted full-fat SB and soybean meal (SBM) contained CP 36.8, 36.0 and 45.9% and EE 18.5, 21.5 and 1.0%, respectively. KOH solubility estimates for extruded full-fat SB, toasted full-fat SB and SBM were 79.9%, 81.3% and 80.2%, respectively and these were not showing any urease activity indicating that these products were reasonably well-prepared and irrespective of the process used, these were neither over- or under-cooked.

3.1. Growth performance

3.1.1 Starter phase (day 1-10)

Growth performance of birds in terms of feed intake, body weight gain and FCR at the end of starting phase (day 1-10) is given in Table 5. During starting phase, feed intake was non-responsive to the dietary treatments indicating that irrespective of the industrial process used for preparing full-fat SB and inclusion levels of full-fat SB the feed consumption by the experimental birds remained the same. Subuh *et al.* (2002) conduct an experiment to check the various ratios of extruded full-fat soybean with solvent extracted soybean meal. Findings were in line with the current study, there was no difference in terms of feed consumption with dietary replacement of solvent extracted SBM with extruded full-fat SB.

Body weight gain (BWG) by chicks in response to dietary treatments during the starting phase was also non-significant *(P>0.05)*. Birds have shown no difference in BWG with main and interaction effects of full-fat soybean processing and inclusion levels. Similar weight gain was observed by replacing soybean meal by either toasted/or extruded full-fat SB up-to 20% inclusion level. Nassiri-Fard et al. (2013) conducted an experiment to study the effect of replacing soybean meal with extruded full-fat soybean on performance parameters of broilers. It was reported that body weight gain and feed conversion ratio of experimental diets containing 5, 10, 15 and 20% of the extruded full-fat soybean remained unaffected. Body weight gain was not affected with the inclusion of extruded full-fat soybean up to 15 % in broiler diets (Mirghelenj et al. 2013).

Feed conversion ratio also remained the same in the birds fed variously processed full-fat SB replacing the soybean meal at various inclusion level *i.e.,* 0, 5, 10, 15 and 20%, respectively. The results indicate that the processed full-fat SB either toasted or extruded could replace soybean without impairing FCR up-to 20% inclusion level. In current study FI, BWG and FCR remained similar at various inclusion levels of processed full-fat SB in replacement of soybean meal. Raw full-fat SB contain trypsin inhibitors when fed as such. Trypsin inhibitors suppress the trypsin activity reducing the protein digestion in chickens. When soybean is processed at adequate temperature, TI are destroyed as these are heat labile. (Rocha et al. 2014) reported that trypsin inhibitor activity was decreased when full-fat SB was subjected to processing. In current study similar growth performance with dietary replacement of SBM with processed full-fat SB indicated the fact that full-fat SB either extruded or toasted was adequately processed. As, no growth suppression was observed due to hampered protein digestibility due to TI activity.

3.1.2. Growing phase (day 11-21)

Growth performance of birds in terms of feed intake, body weight gain and FCR at the end of finishing phase (day 22-32) is given in Table 5. Feed intake of the birds remained non-significant *(P>0.05)* throughout growing phase. Main effect of processing method and inclusion levels imparted no effect *(P>0.05)* on FI. This phenomenon remained the same for interaction effect of processing technique and inclusion levels. Similar FI *(P>0.05)* was observed when interaction effect of various processing technique was observed at different inclusion levels. Growing phase is transition phase of broiler growth production, nutrient requirements are shifted to more of energy as compared to protein. Protein requirements are tend to be higher in early stages while decreased in finishing phase while energy requirements are lower in starting phase as compared to finishing phase. In current study, birds were fed on diets having processed full-fat SB in replacement of solvent extracted SBM. Adequate processing of SB ensures maximum protein quality in terms of available amino acids. No growth depression was observed when SBM was replaced with processed full-fat SB. It represents that all SB products used in current study adequately prepared, so no variation was observed due to replacement of one product with another.

Body weight gain was determined replicate wise at the end of growing phase. Similar *(P>0.05)* BWG was observed in the birds fed on diets having various inclusion levels of differently processed full-fat SB. Main and interaction effects of full-fat SB remained unaffected *(P>0.05)* for BWG. Body weight gain of the birds represents optimum growth of broiler chickens, any of the treatment deficit in terms of nutrients could negatively affect growth performance. Similar BWG was observed in the birds with dietary replacement of SBM with extruded or toasted full-fat SB represent similar nutrients availability to chickens for growth production. Feed conversion ratio of birds fed on diets having variously processed full-fat SB at different inclusion levels was remained same *(P>0.05)* at the end of growing phase.

3.1.3. Finishing phase (day 22-32)

Growth performance of birds in terms of feed intake, body weight gain and FCR at the end of finishing phase (day 22-32) is given in Table 6. During finishing phase, feed intake remained non-responsive to the dietary treatments indicating that industrial process used for preparing full-fat SB and dietary replacement of soybean by processed full-fat SB has no impact on FI.

Body weight gain (BWG) of the birds in response to dietary treatments during the finishing phase was also non-significant *(P>0.05)*. Birds showed no difference in BWG with main and interaction effects of full-fat soybean processing and inclusion levels. Similar weight gain was observed by replacing soybean meal by either toasted/or extruded full-fat SB up-to 20% inclusion level. These findings are in line with Rasool (2017), who reported no effect on growth performance in finishing phase when birds were fed toasted full-fat soybean in 0, 25, 50, 74 and 100% replacement to the soybean meal. In contrast to current study, Mirghelenj et al. 2013 reported reduced weight with dietary replacement of SBM with processed full-fat SB. This fact was might be due to variation in processing technology or origin of full-fat SB. Technology of processing and origin of full-fat SB can affect quality parameter and nutrients concentration. In our study, similar BWG represent the fact that toasting full-fat SB at 90°C for 45 min or extrusion at 145°C for 15-20 sec could replace SBM without having negative impact on growth performance of broiler chickens up to 20%.

Feed conversion ratio also remained the same during finishing phase (day 22-32) in the birds fed variously processed full-fat SB replacing the soybean meal at various inclusion level *i.e.* 0, 5, 10, 15 and 20%, respectively. The results indicate that the processed full-fat SB either toasted or extruded could replace soybean without impairing FCR up-to 20% inclusion level. Nassiri-Fard et al. (2013) conducted an experiment to study the effect of replacing soybean meal with extruded full-fat soybean on performance parameters of broilers. It was reported that body weight gain and feed conversion ratio of experimental diets containing 5, 10, 15 and 20% of the extruded full-fat soybean remained unaffected.

3.1.4 Overall phase (day 1-32)

During overall phase of production, growth performance of birds in terms of feed intake, body weight gain and FCR is given in Table 6. Similar FI of the birds was observed in the birds fed variously processed full-fat SB in dietary replacement of soybean at different inclusion levels. The results indicated that industrial process used for preparing full-fat SB and dietary replacement of soybean by processed full-fat SB has no impact on feed consumption of the birds. Onwumelu et al*.* (2012) reported consistant finding to current study with ditary replacement of SBM by toasted full-fat SB.

Body weight gain (BWG) of the birds in response to dietary treatments during overall phase was also non-significant *(P>0.05)*. Birds have shown no difference in terms of BWG with main and interaction effects of full-fat soybean processing and inclusion levels. Similar weight gain was observed by replacing soybean meal by either toasted/or extruded full-fat SB up-to 20% inclusion level. There was no significant difference in feed intake by birds fed diets with extruded full-fat soybean. Nassiri-Fard et al. (2013) conducted an experiment to study the effect of replacing soybean meal with extruded full-fat soybean on performance parameters of broilers. It was reported that body weight gain and feed conversion ratio of experimental diets containing 5, 10, 15 and 20% of the extruded full-fat soybean remained unaffected. Body weight gain was not affected with the inclusion of extruded full-fat soybean up to 15 % in broiler diets (Mirghelenj et al. 2013). Heger et al. (2016) studied the response of broilers to various conditions of extrusion processing of full-fat soybeans. There was no difference in weight gain with the replacement of soybean meal with extruded full-fat soybean. The body weight gain was improved with the diets having processed full-fat soybeans as compared to the birds fed soybean meal-based diets (Hamilton and McNiven, 2000). There were no significant differences between dietary treatments were observed for live body weight at day 49 and weight gain for the period from 0 to 49 days of age by adding 10% roasted full fat soy bean in broiler diets. Erdaw et al. (2017b) evaluated that by adding protease in roasted full fat soybean-based diet increase the live weight of broiler.

Feed conversion ratio also remained the same during overall phase (day 1-32) in the birds fed variously processed full-fat SB replacing the soybean meal at various inclusion levels *i.e.,* 0, 5, 10, 15 and 20%, respectively. The results indicate that the processed full-fat SB either toasted or extruded could replace soybean without impairing FCR up-to 20% inclusion level. Nassiri-Fard et al. (2013) conducted an experiment to study the effect of replacing soybean meal with extruded full-fat soybean on performance parameters of broilers. In support to our findings, FCR of experimental diets containing 5, 10, 15 and 20% of the extruded full-fat soybean remained unaffected.

3.2. Nutrients digestibility

3.2.1. Crude protein digestibility

The digestibility of crude protein was determined at the end of starter (day 11th), grower (day 21st) and finisher (day 32nd) phases. Main and interaction effects of full-fat SB and dietary SBM replacement levels had no effect digestibility of crude protein during starter, grower and finishing phases of broiler chickens Table 7. This indicate that industrial processing and dietary replacement of soybean by processed full-fat SB had no effect on CP digestibility up-to 20% inclusion levels. Raw full-fat SB contains trypsin inhibitors which hinders digestion of protein. When feed entered through mouth of chicken there is no notable digestion of protein in crop, digestion of protein is initiated in proventriculus by the release HCL and pepsinogen. Pepsinogen is converted into active pepsin by action of HCL lowering the pH. Pepsin initiates protein breakdown by breaking down bonds between leucine-valine, tyrosine-leucine, phenylalanine-phenylalanine and phenylalanine-tyrosine (Leeson and Summers, 2001). Further breakdown of protein continues with autolytic conversion of trypsinogen to trypsin and active enzyme chymotrypsin and elastases by lowering effect of pH by acid release. Raw full-fat SB contains trypsin inhibitors. Trypsin inhibitors hinder the cascade of enzymes functions ultimately reducing breakdown of proteins (Erdaw et al. 2016). Undigested protein is excreted through feces and growth depression is observed when full-fat SB is fed as-such. Trypsin inhibitors are heat labile and damaged when full-fat SB or SBM is exposed to heat. But destruction of trypsin through heat by processing SBM or full-fat SB is critical as heat could damage some part of proteins by making complexes of sugar and proteins in mailard reaction (Newkirk, 2008a). Maintaining quality of protein with maximum destruction of trypsin inhibitors is crucial in SB processing. In current study, no difference in CP digestibility was observed when SBM was replaced with either extruded or toasted full-fat SB at various inclusion levels. This indicates adequate processing of full-fat SB in terms of amino acids availability and trypsin inhibitor activity. Increasing the raw full fat soybean inclusion reduced the crude protein and amino acid standardized ileal digestibility. But digestibility was increased with the addition of microbial proteases in the experimental diets (Erdaw et al. 2017b). Dalólio et al. (2016) reported average values of digestibility coefficients 86.8%, 87.9% and 84.34% for crude protein, essential amino acids and non-essential amino acids, respectively with diets having toasted full fat soybean. Jahanian and Rasouli (2016) reported ileac digestibility of amino acids and crude protein increased by adding processed full fat soybean in broiler diets. Protein solubility and available lysine were decreased *(P<0.05)* were decreased with increasing temperature. Processing time had no effect solubility of protein.

3.2.2. Ether extract digestibility

The digestibility of ether extract was determined at the end of starter (day 11th), grower (day 21st) and finisher (day 32nd) phases Table. 7. Main and interaction effects of full-fat SB and dietary SBM replacement levels had no effect on EE digestibility during starter, grower and finishing phases of broiler chickens. This indicate that industrial processing and dietary replacement of soybean by processed full-fat SB had no effect on EE digestibility up-to 20% inclusion levels. Digestibility of fat mainly occurs in small intestine by action of lipase. In small intestine there is adequate secretion of lipase from early ages (Leeson and summers, 2001). Many factors could reduce digestibility of crude fat *i.e.,* length of fatty acids chain, type of fat, fiber contents (masking effect) of diet, age of chickens, intestinal microflora etc. In current study, digestibility of fat remains the same as solvent extracted SBM was replaces with processed full-fat SB in diets of broiler chicken. Fat molecules remain intact when SB is fed as-such or on full-fat basis, when we fed SBM oil is once extracted and then added again to the diets. Form of the fat had no impact on digestibility of fat. Indicating that full potential of oil contents of SB could be utilized by adding soybean as-such without affecting fat digestibility and ultimately growth performance.

3.3. Apparent metabolisable energy

Apparent metabolisable energy (AME) of the diets was determined on day 10th, 21st and 35th; results are mentioned in Table 8. The AME contents of the diets remained unchanged *(P>0.05)* at the end of starter, grower and finisher phases of broiler chickens. This indicates that processing technology either extrusion or toasting and dietary replacement level of SBM by processed full-fat soybean had no impact on AME of the diet at the end of each phase.

3.4. Nitrogen retention

Nitrogen retention (N_{ret}) was determined at the end of each growth phase including starter (day 10th), grower (day 21st) and finisher (day 32nd). Results are mentioned in Table 8. At the end of each N_{ret} remained the same for various industrial processes of full-fat soybean and different levels of dietary replacement of SBM with processed full-fat SB.

3.5. Apparent metabolisable energy corrected for nitrogen

Apparent metabolisable energy corrected for nitrogen (AMEn) was determined at day 10th, 21st and 32nd is given in Table. 8. At the end of each phase AMEn contents of the diets remained unchanged *(P>0.05)* indicating that processing technology or dietary replacement of SBM with processed full-fat SB has no effect on apparent metabolisable energy contents corrected for nitrogen losses.

Table 5: Effect of various levels of processed full-fat soybean on growth performance

Items		1-10 d			11-21 d		
FFSB	**Level (%)**	**FI**	**BWG**	**FCR**	**FI**	**BWG**	**FCR**
EFSB		307	280.0	1.10	824.9	610	1.36
TFSB		303	278.8	1.09	822.1	604	1.34
SEM		*3.73*	*2.67*	*0.01*	*7.16*	*6.41*	*0.01*
	0	300	280	1.06	810	604	1.34
	5	317	283	1.12	815	615	1.33
	10	307	275	1.11	823	601	1.37
	15	300	282	1.06	813	615	1.32
	20	302	277	1.09	821	608	1.35
SEM		*5.90*	*4.22*	*0.02*	*11.3*	*10.1*	*0.02*
EFSB	0	308	288	1.07	827	615	1.34
	5	315	274	1.15	813	587	1.39
	10	306	276	1.11	826	588	1.40
	15	295	281	1.05	805	613	1.31
	20	311	283	1.10	820	612	1.34
TFSB	0	292	273	1.07	793	596	1.33
	5	319	293	1.08	823	643	1.28
	10	307	273	1.13	807	612	1.32
	15	304	284	1.07	820	616	1.33
	20	294	270	1.09	812	603	1.35
SEM		*8.35*	*5.97*	*0.03*	*16*	*14.3*	*0.03*
P-values							
FFSB		0.50	0.61	0.72	0.80	0.23	0.30
Level		0.22	0.48	0.12	0.07	0.79	0.30
FFSB*Level		0.39	0.05	0.58	0.07	0.10	0.48

Table 6: Effect of various levels of processed full-fat soybean on growth performance

Items		22-32 day			0-32 day		
FFSB	**Level (%)**	**FI**	**BWG**	**FCR**	**FI**	**BWG**	**FCR**
EFSB		1401	909	1.54	2526	1800	1.40
TFSB		1443	938	1.54	2571	1831	1.40
SEM		*19.4*	*16.5*	*0.02*	*23.3*	*22.0*	*0.01*
	0	1409	937	1.50	2520	1822	1.38
	5	1436	914	1.57	2606	1812	1.44
	10	1434	945	1.52	2540	1820	1.40
	15	1401	903	1.55	2512	1800	1.40
	20	1420	918	1.55	2543	1802	1.41
SEM		*30.7*	*26.1*	*0.02*	*36.8*	*34.8*	*0.02*
EFSB	0	1400	935	1.50	2535	1837	1.38
	5	1407	910	1.55	2535	1772	1.43
	10	1390	935	1.49	2513	1800	1.40
	15	1367	886	1.54	2560	1840	1.39
	20	1420	935	1.52	2570	1830	1.40
TFSB	0	1420	938	1.51	2504	1807	1.39
	5	1434	936	1.53	2677	1872	1.43
	10	1400	956	1.46	2556	1840	1.39
	15	1432	960	1.49	2614	1861	1.40
	20	1401	939	1.49	2506	1800	1.39
SEM		*43.4*	*37*	*0.03*	*52.0*	*49.2*	*0.02*
P-values							
FFSB		0.10	0.20	0.94	0.18	0.22	0.69
Level		0.90	0.77	0.29	0.38	0.98	0.15
FFSB*Level		0.40	0.38	0.05	0.20	0.26	0.60

Table 7: Effect of various levels of processed full-fat soybean on nutrients digestibility

Items		11th day			21st day		32nd day	
FFSB	Level (%)	CP	EE		CP	EE	CP	EE
EFSB		76.93	79.44		77.98	80.56	78.79	83.20
TFSB		76.36	79.34		77.05	80.95	79.26	83.80
SEM		*0.41*	*0.39*		*0.50*	*0.34*	*0.51*	*0.34*
	0	77.27	78.85		77.20	79.16	79.83	83.63
	5	75.98	79.60		77.68	80.86	79.35	84.18
	10	76.84	79.30		77.53	80.61	79.86	83.52
	15	76.21	80.49		76.93	81.04	79.58	84.18
	20	76.90	79.15		78.24	82.13	76.50	82.02
SEM		*0.65*	*0.61*		*0.80*	*0.53*	*0.81*	*0.53*
EFSB	0	78.28	79.10		78.69	80.47	80.43	84.03
	5	76.48	78.96		75.65	80.23	79.07	83.46
	10	76.91	79.46		75.28	79.42	79.79	83.06
	15	76.04	80.54		77.14	80.25	80.49	84.79
	20	76.95	79.13		78.48	82.4	74.18	80.68
TFSB	0	76.27	78.61		75.71	77.86	79.24	83.23
	5	75.49	80.22		79.71	81.48	79.63	84.91
	10	76.77	79.15		79.80	81.80	79.94	83.97
	15	76.38	79.55		76.71	81.83	78.67	83.56
	20	76.85	79.16		77.99	81.80	78.83	83.36
SEM		*0.92*	*0.86*		*1.13*	*0.75*	*1.15*	*0.75*
P-values								
FFSB		0.33	0.86		0.20	0.41	0.52	0.22
Level		0.63	0.70		0.81	0.01	0.03	0.04
FFSB*Level		0.73	0.75		0.01	0.02	0.07	0.08

Table 8: Effect of various levels of processed full-fat soybean on AME, Nret and AMEn

Items		10th day			21st day			32nd day		
FFSB	Level (%)	AME	N_{ret}	AMEn	AME	N_{ret}	AMEn	AME	N_{ret}	AMEn
EFSB		2883	2.80	2860	3061	2.69	3040	3170	2.37	3151
TFSB		2860	2.86	2837	3062	2.77	3039	3169	2.33	3150
SEM		*25.1*	*0.03*	*24.9*	*28.3*	*0.02*	*28.3*	*33.3*	*0.05*	*33.0*
	0	2837	2.82	2814	3069	2.80	3046	3165	2.39	3145
	5	2869	2.84	2845	3091	2.75	3068	3187	2.33	3168
	10	2930	2.83	2916	3058	2.70	3035	3181	2.28	3162
	15	2875	2.85	2851	3045	2.77	3023	3162	2.40	3142
	20	2842	2.84	2819	3046	2.65	3025	3156	2.38	3137
SEM		*39.6*	*0.04*	*39.4*	*44.8*	*0.03*	*44.7*	*52.6*	*0.07*	*52.2*
EFSB	0	2851	2.82	2828	3069	2.73	3047	3145	2.36	3126
	5	2926	2.83	2903	3096	2.68	3075	3191	2.33	3172
	10	2942	2.81	2919	3067	2.65	3047	3175	2.37	3156
	15	2875	2.77	2852	3026	2.77	3003	3185	2.43	3165
	20	2826	2.80	2803	3046	2.64	3024	3151	2.38	3131
TFSB	0	2822	2.82	2799	3067	2.86	3045	3184	2.42	3164
	5	2811	2.85	2787	3086	2.82	3062	3182	2.33	3163
	10	2937	2.86	2914	3047	2.75	3024	3187	2.19	3169
	15	2875	2.93	2851	3067	2.78	3042	3139	2.38	3119
	20	2860	2.88	2836	3047	2.65	3025	3161	2.35	3142
SEM		*56.0*	*0.06*	*55.7*	*63.4*	*0.04*	*63.2*	*74.4*	*0.10*	*73.8*
P-values										
FFSB		0.53	0.10	0.52	0.97	0.02	0.99	0.98	0.55	0.97
Level		0.42	0.98	0.42	0.94	0.05	0.95	0.99	0.75	0.99
FFSB*Level		0.73	0.65	0.73	0.99	0.47	0.99	0.98	0.80	0.98

Table 9: Effect of various levels of processed full-fat soybean on gut morphometry

Items		Villus height (µm)	Crypt depth (µm)	Crypt depth: villus height
FFSB	Level (%)			
EFSB		1684	156.5	0.09
TFSB		1707	150.01	0.08
SEM		*30.4*	*2.66*	*0.00*
	0	1724	146	0.08
	5	1704	160.1	0.09
	10	1694.6	153.3	0.09
	15	1636.7	156.1	0.09
	20	1700	149.2	0.08
SEM		*48.1*	*4.21*	*0.00*
EFSB	0	1720.2	152	0.09
	5	1682	165	0.10
	10	1651	154	0.09
	15	1665	160	0.09
	20	1704	150	0.09
TFSB	0	1768	140	0.08
	5	1725	156	0.09
	10	1622	152	0.09
	15	1724	151	0.09
	20	1695.3	148	0.08
SEM		*68*	*5.95*	*0.01*
P-values				
FFSB		0.60	0.09	0.11
Level		0.64	0.18	0.31
FFSB*Level		0.95	0.84	0.87

Table 10: Effect of various levels of processed full-fat soybean on hematology

Items		WBC (x10$^{3-\mu L}$)	RBC (x10$^{6-\mu L}$)	PLT (x10$^{3-\mu L}$)	HGB (dl/l)
FFSB	Level (%)				
EFSB		106.25	9.83	105.3	9.83
TFSB		99.72	9.61	103.9	9.61
SEM		*1.93*	*0.17*	*4.46*	*0.17*
	0	102.3	9.58	107.5	9.58
	5	97.60	9.99	104.93	9.99
	10	108.2	9.67	107.1	9.67
	15	106.5	9.65	104.4	9.65
	20	99.82	9.74	99.5	9.73
SEM		*3.05*	*0.26*	*7.05*	*0.26*
EFSB	0	106.3	10.04	110.7	10.4
	5	101.3	10.01	104.4	10.1
	10	110.7	9.76	107.1	9.78
	15	108.7	9.45	104.4	9.45
	20	104.2	9.91	99.50	9.91
TFSB	0	98.3	9.12	104.5	9.12
	5	93.5	9.98	105.9	9.98
	10	106.8	9.55	106.9	9.55
	15	104.2	9.85	104.5	9.85
	20	95.4	9.56	98.6	9.56
SEM		*4.31*	*0.37*	*9.97*	*0.37*
P-values					
FFSB		0.04	0.23	0.83	0.36
Level		0.13	0.97	0.93	0.82
FFSB*Level		0.97	0.28	0.99	0.53

Table 11: Effect of various levels of processed full-fat soybean on serum profile

Items FFSB	Level (%)	Serum protein	Albumin	Globulin	A:G
EFSB		5.03	1.49	3.25	0.46
TFSB		4.74	1.57	3.04	0.52
SEM		*0.08*	*0.06*	*0.02*	*0.02*
	0	4.93	1.38	3.05	0.45
	5	4.80	1.50	3.15	0.48
	10	4.82	1.78	2.88	0.62
	15	4.90	1.58	3.28	0.48
	20	4.98	1.42	3.38	0.43
SEM		*0.12*	*0.09*	*0.03*	*0.03*
EFSB	0	5.10	1.40	3.20	0.44
	5	5.05	1.45	3.15	0.46
	10	5.10	1.75	2.90	0.60
	15	5.0	1.65	3.45	0.48
	20	4.90	1.20	3.55	0.37
TFSB	0	4.75	1.35	2.90	0.46
	5	4.55	1.55	3.15	0.49
	10	4.55	1.80	2.85	0.63
	15	4.80	1.50	3.10	0.48
	20	5.05	1.65	3.20	0.52
SEM		*0.17*	*0.12*	*0.05*	*0.04*
P-values					
FFSB		0.02	0.33	0.01	0.05
Level		0.82	0.06	0.01	0.01
FFSB*Level		0.30	0.23	0.02	0.24

3.7. Gut morphometry

Gut morphometry in terms of villus height, crypt depth and villus height to crypt depth ratio was determined at the end of finishing phase (32nd day), results are shown in Table. 9. Villus height, crypt depth and villus height: crypt depth remained unchanged with various inclusion levels of processed full-fat SB in replacement to SBM irrespective of processing method used.

3.8. Hematology

Blood chemistry in terms of white blood cells, red blood cells, platelets and hemoglobin concentration of the birds fed variously processed full-fat SB at dietary replacement levels of SBM was determined at the end of experiment (day 32nd), results are shown in table 10. Main and interaction effects of full-fat SB processing and SBM replacement levels has no affect *(P>0.05)* on blood chemistry of broiler chickens.

3.9. Serum biochemistry

Serum biochemistry in terms of serum protein, albumin, globulin and albumin to globulin ratio was determined at the end of finishing phase (day 32nd), results are shown in table 11. Main and interaction effects of full-fat SB processing and SBM replacement levels has no affect *(P>0.05)* on serum profile of broiler chickens.

CONCLUSION

It was concluded that extruded or toasted full-fat soybean could effectively replace soybean meal up to 20% in broiler rations without having adverse effect on growth performance, nutrients digestibility and gut morphometry.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

MMJ performed the experiments and also wrote the manuscript. MAM, AR, and SR helped in planning and execution of research. All authors were involved in finalizing this article.

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