NUTRIENT COMPOSITION, ILEAL AMINO ACID DIGESTIBILITY OF SOYBEAN HULLS ACQUIRED FROM VARIOUS RESOURCES IN BROILER

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Abstract- Nutrient composition and ileal amino acid (AA) digestibility of soybean hulls (SH) collected from four solvent extraction plants (SH1, SH2, SH3 and SH4) in Pakistan, were compared using laboratory analyses and animal studies. For animal studies, 200, day-old birds were randomly divided among five feeding groups, each comprising of four replicates of ten birds in a completely randomized design (CRD) using general linear model (GLM) procedure of the statistical analysis system. There was significant ($P > 0.05$) effect of SH source on percent crude protein (CP), fat, ash, fiber, and non-starch polysaccharide (NSP) of SH originated from different resources. The mean CP percentage of the four SH sources was determined to be 11.6% in SH3 to 13.52% in SH1 ($P < 0.05$) on as-fed basis. The ileal amino acid digestibility (IAA) of SH obtained from different commercial plants were significantly different. In general, SH1 and SH4 fed birds had significantly higher ileal amino acid digestibility as compared to those fed SH2 and SH3 on all recorded stages of the experiment. Substantial differences ($P < 0.05$ to $P < 0.01$) were observed for the digestibility of lysine, methionine + cystine, glycine + serine, leucine and phenylalanine of SH procured from different resources. It is concluded that nutritive values and digestibility vary among SH originated from different sources and contribute differently to performance of the birds. Overall, nutritive value of SH1 was superior in contrast to that of SH2, SH3 and SH4 and contents of IAA digestibility.

Key words: Amino acid digestibility, ileal, amino acid digestibility, broiler, soybean hulls

I-INTRODUCTION

The cost for major traditional feed ingredients is continuously increasing for animal production, whereas utilization of low-cost by-products is not only economical but also sustainable (Wang et al., 2021). The use of a less expensive feed ingredient while still maintaining bird growth has been practiced over the past few years in poultry industries. Feed ingredients used to formulate a diet could affect the development of the gastrointestinal tract (GIT) and the utilization of nutrients in broiler chickens, thereby affecting the production performance of birds (Hartini and Rahardjo, 2018; Yegani and Korver, 2008). Apart from what kind of feed ingredients are used in formulating broilers diets, it should be noted that the two main targets in poultry production are high growth rate and feed efficiency (Hartini and Rahardjo, 2018; Sugiharto, 2016). As a matter of fact, feed costs almost 3/4th of the total cost of production which means that any attempt to reduce feed cost may cause a considerable reduction in the total cost of production (Thirumalaisamy et al., 2016).

Many of the ingredient composition tables used by poultry nutritionists do not list the composition for SH. Tables in some foreign publications (e.g., Brazilian tables for poultry and swine) list values for SH; however, these values may be influenced by soybean source and processing techniques. Research to determine the nutritional values of SH obtained from soybean available in Pakistan has not been completed. This study was, therefore, conducted to investigate the nutrient composition of SH obtained from different resources for further utilization in economical feed formulation with no adverse effects on the performance of broiler chickens.

1.1.Objectives

The objectives followed in this study were

i. To determine the nutritional value of SH procured from solvent extraction plants in Pakistan for better utilization in broiler diets.
ii. To evaluate the nutritional value of SH procured from different solvent extraction plants in Pakistan for better utilization in broiler diets
iii. To measure the ileal amino acid digestibility of different SH in broiler.

II-MATERIAL AND METHODS

The ever-increasing prices of conventional feed ingredients compel the animal scientists all over the world in general and poultry nutritionists in specific to search for alternative feed ingredients which can complement least cost feed formulation without affecting the performance. Inclusion of any feed ingredient in the diet depends on its nutrient composition, as well as digestibility measurements of those nutrients. Classified among alternative feed ingredients, soybean hull (SH) is an agro-industrial residue, with very less reliable data available. Keeping in view, the limitations of private poultry feed industry, this research was planned to evaluate the nutrient composition and digestibility of SH available in Pakistan. This study was a joint venture of academia and private poultry sector.

This study was deliberated to establish the chemical profile and amino acids digestibility of SH acquired from several suppliers on d14, d2l, d28, and d35 of age using broiler modulation. The trial was carried out at Research & Development Center, SB Feeds (Pvt.) Ltd. Rawalpindi.

2.1 Availability of Birds and Experimental Diets

One thousand, day-old chicks used in this experiment were purchased from local hatchery. All the birds were reared together on floor system and fed commercial diets till the age of d7. The standard corn-soybean meal-based diet called basal diet was formulated (Table 3.1) with the minimum requirement of chicks (NRC, 1994). The four test diets were prepared by replacing 25% (wt/wt) of the basal diet with one of the four sources of soybean hulls (SH). Celite, a source of acid insoluble ash as an external digestibility marker was included in the test diets. On day 8, 200 birds out of 1000 were shifted to 20 cages, in a manner that 10 birds were placed in each cage. Out of those 200 chicks, 40 were placed in 4 pens and were provided basal commercial ration formulated for the trial from d8 to dl4. The other 160 chicks were placed in 16 pens in such a way that 40 birds in 4 cages received one of the four test diets (developed by replacing 25% (wt/wt) of the basal diet with one of the four sources of SH) from d8 to dl4. The chicks receiving either basal or test feed were given first four days (d8 to d11) of adaptation period. Feed intake and fecal output was monitored thrice daily for last three days (d12 to d14). The same process was adopted for the remaining birds till the age of d21, d28 and d35 respectively. All the ingredients including SH were purchased locally, and mixed in Feed Mill unit of SB Feeds, Mandra. The experimental chicks received one of the four test rations from 8 – 14, 15 – 21, 22 – 28 and 29 – 35 day of age.

Table 1. Ingredient composition of basal diet used for the determination of ileal amino acid digestibility in broiler chicks.

Ingredient (%)	Percentage
Corn	58.00
Soybean meal	34.50
Soybean oil	2.50
Limestone, $CaCO_3$	0.80
Dicalcium phosphate, DCP	2.10

$NaCl_2$	0.25
$NaHCO_3$	0.35
Vit:Min premix[1]	0.50
Celite[2]	1.00
Total	100.00

[1] Each kg of the feed contained: Retinyl acetate (vit A), 4400 IU; Cholecalciferol (vit. D_3), 118 pg; DL-α-Tocopherol acetate (vit. E), 12 IU; Menadione sodium bisulfite (MSB, vit. K3), 2.40 mg; Thiamin (vit. B1), 2.5 mg; Riboflavin (vit. B2), 4.8 mg; Niacin (vit. B3), 30 mg; Pantothenic acid (vit. B5), 10 mg; Pyridoxine (vit. B6), 5 mg; Biotin (vit. B7), 130 µg; Folic acid, 2.5 mg; Cyanocobalamin (vit. B12), 19 µg; Manganese, 85 mg; Selenium, 130 µg; Zinc, 75 mg; Iron, 80 mg; Iodine, 1.0 mg; Copper, 6 mg.

[2] Celite: Acid insoluble ash added as an indicator of digestibility.

Table 2. Composition of soybean hulls-based test diets used in the experiment

Diet[1]	**Basal diet**	**SH_1**	**SH_2**	**SH_3**	**SH_4**
	------------------------	------------	%	------------	------------------------
Basal diet Control)	100	-	-	-	-
Soybean Hulls (SH_1)	75	25	-	-	-
Soybean Hulls (SH_2)	75	-	25	-	-
Soybean Hulls (SH_3)	75	-	-	25	-
Soybean Hulls (SH_4)	75	-	-	-	25

[1] Basal diet = Standard corn-soybean meal diet; SH_1 = soybean hulls acquired from SB Feeds Mandra; SH_2 = soybean hulls acquired from Shabbir Feeds Multan; SH_3 = soybean hulls acquired from Sind Feeds Karachi and SH_4 = soybean hulls acquired from Hi-Tech Feeds Lahore.

Table 3. Ingredient composition of nitrogen free diet (as fed basis)

Ingredient	Percentage
Corn starch	17.0
Dextrose	64.0
Soybean oil	5.00
Arbocel (cellulose)[1]	5.00
Celite[2]	1.00
Di-Calcium Phosphate, DCP	2.00
Limestone, CaCO3	1.50
Vitamin mineral premix[3]	0.80
Choline Chloride	0.40
NaCl	0.20
$NaHCO_3$	1.50
KCl_2	1.60

[1]Arbocel, Insoluble raw fiber concentrate, Holzmuhle, Rosenberg, Germany.

[2]Celite: a source of acid insoluble ash as an external digestibility marker. [3]Each kg of the premix contained: Retinyl acetate (vit A), 4400 IU; Cholecalciferol (vit. D_3), 118 pg; DL-α-Tocopherol acetate (vit. E), 12 IU; Menadione sodium bisulfite (MSB, vit. K3), 2.40 mg; Thiamin (vit. B1), 2.5 mg; Riboflavin (vit. B2), 4.8 mg; Niacin (vit. B3), 30 mg; Pantothenic acid (vit. B5), 10 mg; Pyridoxine (vit. B6), 5 mg; Biotin (vit. B7), 130 µg; Folic acid, 2.5 mg; Cyanocobalamin (vit. B12), 19 µg; Iron, 80 mg; Manganese, 85 mg; Copper, 6 mg; Selenium, 130 µg; Iodine, 1 mg; Zinc, 75 mg.

Table 4. Experimental layout

Diet	Replicates for ME and ileal amino acids digestibility			
Basal diet (Control)	10	10	10	10
Soy Hulls (Source A)	10	10	10	10
Soy Hulls (Source B)	10	10	10	10
Soy Hulls (Source C)	10	10	10	10
Soy Hulls (Source D)	10	10	10	10

2.2 Housing and Experimental Environment

For the experiment trial broiler chicks were procured from the native market. The chicks were brooded a commercial broiler ration and then raised on the basal diet, or one of the four SH based experimental diets up to thirty-five days of age. The chicks were kept on saw dust floor in an open sided, properly ventilated house. Equipment like feeders and drinkers were provided to maintain uniform environmental and management conditions in the experimental house. All experimental birds were vaccinated according to standard vaccination program for broiler chickens. The trial was continued for 35 days of age; however, experimental rations were provided from day 8 to day 35 for different age groups of birds.

2.3 Digesta Collection for Apparent Metabolizable Energy

The experimental diet was provided for a week, with first four days serving as an adaptation period. During the last three days, intake of feed was recorded. On d12, birds from all experimental units were subjected to classical total excreta collection method. Excrements of each cage were accumulated, weighed, and pooled within the cage on daily basis. The excreta were separated from feathers and feed particles to best possible effort, thoroughly mixed and freeze-dried. These freeze-dried samples were then crushed down using a 0.5mm screen and collected in airtight containers at -4°C for gross energy determination. Similar process was repeated for other three groups on d19, d26 and d33 respectively (Ravindran et al., 2014).

2.4 Ileal Digesta Collection and Processing

Ileal digesta was collected and processed following the technique adopted by (Ravindran et al., 2014). Briefly, on day 14, at least four birds from each cage were euthanized and then slaughtered. Digesta from the ileal portion of small intestine (from Meckel's diverticulum to 40 mm proximal downward to cecum) was flushed out with distilled water into plastic containers, pooled, chilled at -20°C and then freeze-dried. The samples of dried ileal digesta samples were ground by passing through a 0.5mm sieve and kept at -4°C for further chemical assessment. Similar process was repeated for other three groups on d21, d28 and d35 respectively.

Basal endogenous amino acid flow was determined in sidewise assay (Ravindran et al., 2008). In this assay, forty birds were placed in four replicates of ten birds each and offered protein free diet from d29 to d35. On day 36, the birds were euthanized and ileal digesta was gently flushed into sampling tubes using distilled water. Samples from each replicate were pooled, homogenized, frozen and freeze-dried soon after collection. These samples were then dissolved in deionized water and the mixture made acidic to pH 3.5 using 9M H_2SO_4. After 24 hours of storage at 4˚C, the samples were then centrifuged at 1450 g for 45 min at 0˚C. The supernatant fraction was emptied out and preserved while the precipitate was centrifuged again at 1450 g for ½ hours at 0˚C after washing with 10 ml deionized water. The precipitate was stored at -20˚C while the supernatant fraction was mixed with the first one and filtered through ultrafiltration device according to the manufacturer's instructions. This ultrafiltered supernatant and the stored precipitate were freeze dried. These freeze-dried samples were then crushed down using a 0.5mm screen and collected in airtight containers at -4°C for further analyses.

2.5 Chemical Assays

Samples of experimental diet and ileal digesta were subjected to DM, CP, CF, EE, Ash, NFE and AIA calculation according to procedure laid by (Official, 2000). Similarly, amino acid profiles of experimental diets and ileal digesta were calculated according to the procedure adopted by Abdollahi et al. (2015). In brief, the samples were hydrolysed with 6 N HCl (having phenol) overnight at 110 ± 3°C in airtight glass tubes. The AA were sensed on a LC-6AD liquid chromatograph (Shimadzu Japan), SPD-M20A PDA Detector (Shimadzu) and CBM-20A Communication Bus Module. Shimadzu LAB Solutions (v. 5) software was used for the analyses. Amino acids were adsorbed using a gradient solution consisting of pH 3.3 sodium citrate eluent to pH 9.8 sodium borate eluent at a flow rate of 0.4 mL/min and a column temperature of 60°C. Cysteine and methionine were oxidized in performic acid for 16 hours at 0°C, neutralized using hydrobromic acid, and finally hydrolyzed to cysteic acid and methionine sulfone, respectively.

The digestibility coefficients of diets ($AIAADC_d$) and SH ($AIAADC_{SH}$) were calculated using the equation 1 and 2, below, respectively.

1. $$AIAADCd = \frac{\left(\frac{AA}{AIA}\right)d - \left(\frac{AA}{AIA}\right)I}{\left(\frac{AA}{AIA}\right)d}$$

Whereas $(AA/AIA)_d$ represented the ratio of amino acid (AA) to acid insoluble ash (AIA) in the diet, while $(AA/AIA)_i$ represented the ratio of AA to AIA in the ileal digesta.

2. $$AIAADCSH = \frac{(AIAADC[SHD] \times AA[SHD]) - (AIAADC\ [BD] \times AA\ [BD]) \times 0.75}{(0.25 \times [AA\ ])}$$

Whereas SHD = Soybean hulls diet; BD = Basal diet

The following formula was used to calculate standardized ileal amino acid digestibility coefficient:

$$SIAADC = AIAADC + (BEAA\ (g/kg\ DM\ intake))/(ingAA\ (g/kg\ DM))$$

Where SIAADC = Standardized ileal amino acid digestibility coefficient

BEAA = Endogenous amino acid in the basal diet

Ing. AA = Amino acid in SH.

2.6 Chemical composition

Respective samples from each replicate were appropriately thawed and pooled to make a homogenous sample and oven-dried at 60 °C for 3 days. After air-drying, these representative samples were crushed to a 0.5mm particle size, kept at room temperature in respective sample containers. Each sample of feces and feed were analysed for determination of chemical composition i.e. Dry Matter (DM), Ether extract (EE), Crude protein (CP) and Nitrogen free extract (NFE).

2.7 Nutrients' digestibility

Digestibility of dry matter and organic matter was recorded by the dissimilarity amongst the nutrients expended and excreted by the birds in feces with the following formula.

$$\text{Digestibility } \% = \frac{Y - Z}{Y} \times 100$$

Whereas,

Y = Amount of nutrient utilized by the birds (g/d)

Z = Amount of nutrient excreted by the birds in feces (g/d)

2.7 Statistical Analysis

The data were analyzed by the analysis of variance (ANOVA) technique in a completely randomized design (CRD) using general linear model (GLM) procedure of the statistical system (SAS, 2006). Duncan's multiple range test was applied to separate the means at probability (P) value of less or equal to 0.05.

III- RESULTS

The data for chemical composition of SH acquired from different resources are shown in Table 3.3.1. There was significant ($P < 0.01$) effect of dietary source on the chemical composition of SH obtained from different solvent extraction plants. Crude protein contents ranged from 11.6% in SH3 to 13.52% in SH1 ($P < 0.05$). Similarly, the recorded values of crude fiber, ash, NDF, ADF, NFE, GE and ME differed significantly ($P < 0.05$) among different SH sources. Crude fiber content ranged from 30.90% in SH1 to 35.76% in SH2. SH1 and SH4 had significantly ($P < 0.05$) higher and same GE (3892.11 and 3902.03, kcal/kg, respectively) while lowest and same for SH2 (3691.9, kcal/kg) and SH3 (3692.31, kcal/kg). Similar trend was observed for ME of different SH groups.

Table 3.1 Chemical composition of soybean hulls acquired from different sources in Pakistan

Nutrient	------------ Soybean Hulls[1] ------------				Pooled SEM	P-value
	SH_1	SH_2	SH_3	SH_4		
Moisture, %	9.80[a]	8.66[b]	8.82[b]	9.64[a]	0.095	0.029
CP, %	13.52[a]	11.60[c]	11.84[c]	12.77[b]	0.103	0.027
Crude fiber, %	30.90[c]	35.76[a]	35.51[a]	33.57[b]	0.084	0.034
Total P %	0.14	0.12	0.10	0.12	0.058	0.195
Av. P %	0.11	0.10	0.10	0.10	0.034	0.976
Ash %	4.25[b]	5.05[a]	5.03[a]	4.58[b]	0.094	0.013
Ca, %	0.63	0.52	0.49	0.61	0.065	0.336
NDF, %	37.21[c]	55.29[a]	55.11[a]	45.38[b]	0.084	0.0055
ADF, %	34.67[b]	45.08[a]	44.96[a]	42.07[a]	0.075	0.0179
Fat, %	1.54	1.96	1.88	2.03	0.092	0.964
NFE, %	36.57[b]	39.96[a]	41.93[a]	37.10[b]	0.089	0.0360

Data for ileal amino acid digestibility (IAA) are summarized in Table 3.2. Significant differences ($P < 0.05$) were observed in the IAA of SH from different commercial mills. In general, SH1 and SH4 fed birds had significantly higher ileal amino acid digestibility as compared to those fed SH2 and SH3 on day 14 (Table 3.3.2), day 21 (Table 3.3.3), day 28 (Table 3.3.4) and day 35 (Table 3.3.5) of the experiment. On day 14, digestibility of lysine, methionine+cystine, glycine+serine, and valine, was significantly ($P < 0.05$) higher and same for SH1 and SH4 while lowest and same for SH2 and SH3. Digestibility of arginine was significantly higher for SH1 followed by SH2 while lowest and same in SH3 and SH4. Similar trend was observed on day 21 of the experiment for lysine, methionine+cystine and phenylalanine. Glycine+serine digestibility was significantly ($P<0.05$) higher for SH1 followed by SH2 while lowest and same for SH3 and SH4. Digestibility of arginine was significantly ($P<0.05$) higher for SH1 as compared to other treatment groups. On day 28 of the experiment, significant variations were recorded in the ileal digestibility of most of the amino acids. Digestibility of lysine, arginine, valine, leucine phenylalanine and phenylalanine+tyrophane was significantly higher for SH1 followed by SH2 while lowest and same for SH3 and SH4. Digestibility of methionine+cystine was significantly higher ($P < 0.05$) for SH1 (0.190) while lowest for SH3 (0.173%). Similar trend was observed on day 35 of the experiment. glycine+serine content was highly digestible ($P < 0.05$) in SH1 (0.781%) followed by SH2 (0.741%) while lowest and same for SH3 (0.713%) and SH4 (0.705%). Similarly, Leucine and Phenylalanine were highly digestible for SH1 diet while lowest in SH3 on day 35 of the experiment. There was no significant difference ($P > 0.05$) in the ileal digestibility of the rest of amino acids.

Table 3.2 Comparative efficacy of soybean hulls acquired from different solvent extraction plant on the basis of apparent metabolizable energy values and ileal amino acid digestibility (%) on day 21 in broiler

Diet[1]	**SH_1**	**SH_2**	**SH_3**	**SH_4**	**Pooled SEM**	**P-value**
AME, kcal/kg	990.0[a]	910.0[b]	914.0[b]	984.0[a]	25.21	0.0228
CP	13.83[a]	11.47[b]	11.45[b]	13.62[a]	1.0900	0.0061
Lysine	0.541[a]	0.513[b]	0.493[b]	0.539[a]	0.0063	0.0070
Methionine+cysteine	0.190[a]	0.180[a]	0.173[b]	0.179[a]	0.0018	0.0363
Tryptophane	0.059	0.056	0.054	0.058	0.0002	0.0767
Glycine+serine	0.770[a]	0.731[b]	0.703[c]	0.695[c]	0.0100	0.0221
Isoleucine	0.340	0.322	0.310	0.320	0.0036	0.0646
Histidine	0.180	0.171	0.164	0.177	0.0018	0.0686
Methionine	0.110	0.105	0.101	0.105	0.0009	0.0847
Threonine	0.240	0.228	0.219	0.229	0.0027	0.0702
Arginine	0.651[a]	0.607[b]	0.593[b]	0.597[b]	0.0082	0.0209
Valine	0.381[a]	0.361[b]	0.347[c]	0.367[b]	0.0045	0.0072
Leucine	0.590[a]	0.560[b]	0.539[c]	0.559[b]	0.0073	0.0597
Phenylalanine	0.371[a]	0.341[b]	0.337[b]	0.367[a]	0.0045	0.0005
Phenylalanine+tyrophane	0.671[a]	0.636[b]	0.611[c]	0.641[b]	0.0082	0.0385

Table 3.3. Comparative efficacy of soybean hulls acquired from different solvent extraction plant on the basis of apparent metabolizable energy values and ileal amino acid digestibility (%) on day 35 using in broiler.

Diet[1]	SH_1	SH_2	SH_3	SH_4	Pooled SEM	P-value
CP	13.884^a	11.522^c	11.501^c	12.673^b	1.3800	0.0197
Lysine	0.548^a	0.520^b	0.500^c	0.496^c	0.0253	0.035
Methionine+cysteine	0.193^a	0.180^b	0.170^c	0.192^a	0.0072	0.0426
Tryptophane	0.060	0.057	0.055	0.059	0.0007	0.0613
Glycine+serine	0.781^a	0.741^b	0.713^c	0.705^c	0.0398	0.0496
Isoleucine	0.345^a	0.321^b	0.315^b	0.342^a	0.0145	0.0116
Histidine	0.183	0.174	0.166	0.180	0.0072	0.0548
Methionine	0.111	0.106	0.102	0.106	0.0036	0.0677
Threonine	0.243	0.231	0.222	0.232	0.0109	0.0561
Arginine	0.660^a	0.616^b	0.601^b	0.656^a	0.0326	0.0503
Valine	0.386^a	0.366^b	0.362^b	0.376^a	0.0181	0.0061
Leucine	0.598^a	0.568^b	0.546^c	0.567^b	0.0289	0.0477
Phenylalanine	0.376^a	0.356^{ab}	0.342^b	0.352^{ab}	0.0181	0.0484
Phenylalanine+tyrophane	0.680	0.645	0.620	0.650	0.0326	0.0509

IV- DISCUSSION

The data for chemical analysis of soybean hulls (SH) acquired from different resources are reviewed in Table 3.1. There was significant ($P < 0.01$) effect of dietary source on the chemical composition of SH obtained from different solvent extraction plants. Crude protein contents ranged from 11.6% in SH3 to 13.52% in SH1 ($P < 0.05$). Similarly, the calculated values of crude fiber, ash, NDF, ADF, NFE, GE and ME differed significantly ($P < 0.05$) among different SH sources. Crude fiber content ranged from 30.90% in SH1 to 35.76% in SH2. SH1 and SH4 had significantly ($P < 0.05$) higher and same GE (3892.11 and 3902.03, kcal/kg, respectively) while lowest and same for SH2 (3691.9, kcal/kg) and SH3 (3692.31, kcal/kg). Similar trend was observed for ME of different SH groups. The chemical composition of the SH can be influenced by many factors including processing procedure and growing conditions for the soybeans. These data indicate that the chemical composition of SH can be highly variable; however, CF content can help explain much of the variation in CP, ADF, NDF, and energy content (Barbosa et al, 2008). Thus, most of the nutrient values for SH that are required for diet formulation can be estimated from laboratory analysis of the CF and CP level. To some extent, the nutritional value of SH is likely to change with change in the chemistry of the hulls. Just like other byproducts and feed residues, the chemical composition of SH frequently differs largely from one processor plant to other (Barbosa et al, 2008, Arosemena et al., 1995; Belyea et al., 1989). Sometimes, a part of this discrepancy can be shown by treating both, soybean (SB) mill run and SB mill feed, as soyhulls (SH) (Titgemeyer, 2000). In contrast to SB mill run and SB mill feed, which is composed of both meat and hulls, SH are primarily composed of the outer seed coat. Besides this, variations in processing systems and procedures (DePeters et al., 1997), dearth of detailed quality-control programs at the time of extraction and processing of residual feedstuff (Belyea et al., 1989), genetic variations in the crop used for extraction (Westgate et al., 2000), and differences in cultural (e.g., planting date and nitrogen fertilization) and environmental (e.g., temperature and water supply) conditions during SB growth (Westgate et al., 2000) are some of the factors apparently resulting in variable chemical composition of SH. Miron et al. (2001) reported that almost 80% of dry matter in SH is composed of carbohydrates, primarily polymers of glucose and the majority (approx. 75%) of which are obtained from polysaccharides retrieved in the neutral detergent fiber. This can be attributed to the fact that hulls primarily comprise of thick cell wall (approx. 62% of SH DM) to protect the endosperm of the soybean grains, and (van Laar et al., 1999).

As per the NRC (2001), 60.3% of SH dry matter (DM) comprises of neutral detergent fiber (NDF) while the remaining 44.6% is composed of acid detergent fiber (ADF). Nonetheless, variation has been found in the fiber content of SH previously (Barbosa et al, 2008, 2002b; Miron et al., 2001; Shiver et al., 2000), and the main reason for this variation has been attributed to the presence of protein content in the SH (Titgemeyer, 2000). According to Anderson et al. (1988) 73.7% of properly washed SH consisted of NDF and 50.8% ADF. On the other hand, according to DePeters et al. (1997), the calculated amount of NDF and ADF in SH containing some meat was 57.5% and 45.4%, respectively. The fiber fraction of SH is poorly lignified due to presence of approx. 43% cellulose and 18 % hemicellulose on dry matter basis (Barbosa et al, 2008). The average CP recorded in this trial (12.4%, [Table 3.5]), was within the reported range of NRC (2001) (13.9% ± 4.6). Earlier analysis reported CP content ranged from 9.0% to 26.7% (Barbosa et al., 2008). Similarly, Rostagno et al. (2011) reported 13.88% CP for SH, 9.6% by Shiver et al., 2000 and 9.4 % by Anderson et al. (1988). At the same time, Batajoo and Shaver (1998) reported higher CP content (approx. 19.2%) in SH having higher amount of starch (approx. 9.4%) and attributed it to the presence of some meat in the hulls.

Ileal amino acid digestibility

Data for ileal amino acid digestibility (IAA) are summarized in Table 3.3.2 to 3.3.5. Significant differences ($P < 0.05$) were observed in the IAA of SH from different commercial mills. In general, SH1 and SH4 fed birds had significantly higher ileal amino acid digestibility as compared to those fed SH2 and SH3. Because of the high variability in CP levels, it was not surprising that individual amino acids were highly variable between soy hull sources. When expressed relative to the CP content in the SH, most of the variability can be explained (Barbosa et al., 2008).

Much like SBM, SH contains large quantity of Lys (up to 0.72% of DM), and to lesser amount of Met and Cys, (about 0.33% of DM) (Cunningham et al., 1993; Degussa, 1996). Amino acid contents of feedstuffs vary greatly and depend on the CP content of the ingredient. In contrast with CP of the SBM, SH contains lesser amount of Arginine (approx. 35%), Isoleucine (approx. 27%), Leucine (approx. 25%), Valine (approx. 16%), Phenylalanine (approx. 28%), Threonine (approx. 16%), and Tryptophane (approx. 18%), but contains higher amount of Tyrosine (approx. 30%) (Rostagno et al., 2011; Barbosa et al., 2008; Degussa, 1996). Typically, CP extracted from SH has a smaller amount of nonessential AA (approx. 3.5% less than CP of the SBM), however, SH has surprisingly high Glycine content (about 48% more than SBM) (Rostagno et al., 2011; Barbosa et al., 2008; Degussa, 1996). Just like CP content of SH, there is significant variation in the fat content (ether extract) of SH (Ipharraguerre and Clark, 2003), however, no clear association of fat with CP or NDF concentration can be found (Titgemeyer, 2000). To explain this, Belyea et al. (1989), for instance, reported ether extract, NDF and CP of three SH sources to be averaged 4.3%, 72.5%, and 11.8%, whereas the respective values of ether extract, NDF and ADCP were 4.4%, 57.5% and 13% according to DePeters et al. (1997) indicating no clear association of fat with CP or NDF concentration of the SH.

CONCLUSION

The available data on the inconsistency present in the nutrient profile and digestible AA of different soybean hulls (SH) is very scarce.

1) Results of this study revealed significant effect of source on the nutrient profile and digestibility of CP and AA, of SH acquired from various sources.

2) Overall, SH1 had better nutrient composition and IAA digestibility in contrast to SH2, SH3 and SH4.

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