

**EVALUATION OF NUTRITIONAL VALUE AND PROTEIN QUALITY OF
RAW AND DIFFERENTIALLY PROCESSED SWORD BEAN
[*Canavalia gladiata* (Jacq.) DC.] SEEDS****Vadivel V^{1,2}, Doss A³ and M Pugalenth^{3*}****Muthiah Pugalenth****Vellingiri Vadivel****Asirvatham Doss**

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ABSTRACT

Conventional legume seeds have been playing a key role as a source of protein in the diets of both human beings and animals, but their production is not sufficient to meet the increasing protein requirements, particularly in a developing country like India. To meet the inadequate supply of proteins in developing countries, where animal protein is grossly insufficient and also relatively expensive, recent research efforts are being geared towards finding out novel and economic sources of food proteins. Among the various alternative protein sources, the under-utilized legume seeds received more attention, whose protein potential remains under-developed. In this present study, the effect of various common processing methods on the nutritional value, antinutritional compounds, biological value and protein quality of seed materials of a South Indian under-utilized food legume, sword bean (SB) (*Canavalia gladiata* (Jacq.) DC.) was investigated. The mature raw SB seeds contained 28.39% of protein, 7.84% of lipid, 8.23% of fiber, 5.63% of ash and 49.91% of carbohydrates. The autoclaving treatment was more effective in reducing the maximum levels of various antinutritional compounds such as total free phenolics (91%), tannins (85%), L-Dopa (92%), phytic acid (83%), raffinose (84%), stachyose (66%), verbascose (83%), haemagglutinating activity (88%), trypsin inhibitor activity (75%) and α -amylase inhibitor activity (65%) without affecting the nutritional value of SB seeds when compared to soaking, cooking or roasting treatments. The rats fed with the experimental diet containing autoclaved SB seeds as a protein source exhibited better growth performance such as feed intake (219 g) and body weight gain (58 g). Moreover, the protein quality parameters such as true digestibility, biological value, net protein utilization and utilizable proteins were higher in the experimental diet containing autoclaved SB seeds as a protein ingredient. Hence, such autoclaving treatment could be recommended for the utilization of SB seeds as an alternative/additional protein source in the diets of human beings/animals.

Key words: *Canavalia gladiata*, sword bean, protein

INTRODUCTION

Sword bean (SB) (*Canavalia gladiata* Jacq.) is a tropical under-utilized food legume, widely distributed in the Eastern and Western Ghats of South India and also cultivated as a fodder crop in Northern and Peninsular India [1]. It has many desirable agronomic features such as high biomass production, resistance to drought, pest and diseases, high fertility index and high seed productivity (800-1000 Kg/ha) on fertile land, which enable them to grow well under tropical conditions [2]. In India, the SB seeds are consumed by certain ethnic groups and poor village people [3]. In Asia, the young pods and seeds of SB are used as a green vegetable. The SB seeds are often consumed as curries and as a substitute for mashed potatoes and the immature pods are made into a dish directly or often boiled with water in Sri Lanka. The roasted seeds are used to prepare a coffee-like drink in Latin America [4, 5]. The SB seed materials were reported to contain appreciable levels of protein (26-30%), desirable amino acids, fatty acids, starch (34-40%) and good mineral composition [3, 4]. The nutritive value and protein quality of SB seeds seems to be similar to that of most of the edible legume grains and hence, they are advocated to be a good source for extending protein-sources [2 - 5].

Despite the desirable nutritive features, the SB seeds are not extensively utilized as food/feed mainly due to the presence of certain antinutritional compounds [2, 3]. Presence of antinutritional compounds such as total free phenolics, tannins, Concanavalin A (Con A) lectin, L-Canavanine (a non-protein amino acid), phytic acid, oligosaccharides, protease inhibitors and α -amylase inhibitors were reported in the raw SB seeds [2, 3, 6]. Although, few reports are available on the nutritional value and antinutritional compounds of SB seeds, only limited information is available on the effect of certain common processing methods on the levels of nutritional and antinutritional profiles of SB seeds. Identification of suitable processing method will enhance the opportunities for the versatile utilization of SB seeds as an alternative/additional and economic source of protein in the diets of human beings/animals. Hence, the present study was carried out to evaluate the nutritional value, antinutritional profiles, biological value and protein quality of raw and differentially processed SB seeds collected from South India with a view to identify a viable processing device, which will remove the maximum levels of antinutritional compounds without affecting the nutritive quality of SB seeds.

MATERIALS AND METHODS

Collection of the seed materials

The seed materials of sword bean (SB) (*Canavalia gladiata* (Jacq.) DC.) were collected from Bharathiar University Campus, Coimbatore, Tamil Nadu, South India (Fig- 1). Soon after collection, the immature and damaged seeds were removed and the mature seeds were dried in the sun-light for 24 h and stored in plastic containers in a refrigerator (5°C), until further use.



Figure 1:The seed materials of sword bean (SB) (*Canavalia gladiata* (Jacq.) DC.) collected from South India

Processing methods

The whole seeds of SB were randomly separated into five batches (25 g each) and the first batch was soaked in distilled water for 6 h at room temperature ($30 \pm 2^\circ\text{C}$) at a bean to water ratio of 1:10 (w/v). The second batch of seeds was cooked at $90\text{-}95^\circ\text{C}$ for 1 h at a bean to water ratio of 1:10 (w/v). The third batch of seeds was taken at a bean to water ratio of 1:10 (w/v) in a metal container and autoclaved at 15 lb pressure (121°C) for 30 min. The fourth batch seeds was roasted for 30 min at $100\text{-}110^\circ\text{C}$ in an iron pot along with clean fine sand to prevent the burning of the seed coat. The fifth batch of raw seeds was stored as such without any treatment. After each treatment, the processed seed samples were rinsed with distilled water separately and then dried at 55°C for 6 h in a hot air oven.

Proximate composition

All the processed as well as raw seed samples were powdered in a Wiley Mill to 60-mesh size and the powdered samples were used for further analysis. The proximate composition such as moisture, crude protein, crude lipid, crude fiber and ash content of the raw and differentially processed SD seed samples were determined by following AOAC method [7]. Nitrogen free extractives (NFE) and calorific value were calculated by following the method of Siddhuraju *et al.* [8].

Antinutritional compounds

The antinutritional compounds such as total free phenolics and tannins content of raw and differentially processed seed samples were determined by spectrophotometric methods [9, 10]. The L-Dopa (L-3,4-Dihydroxy-phenylalanine) content was quantified at 282 nm, whereas the phytic acid content was determined by multiplying the amount of phytate phosphorous with the factor 3.55 based on the empirical formula $\text{C}_6\text{P}_6\text{O}_2\text{H}_{18}$ [11, 12]. The oligosaccharides were separated by TLC and quantified by treating with 1 ml of 0.2 M thiobarbituric acid [13, 14]. The haemagglutinating activity was analyzed in the presence of 10 mM Mn^{2+} in round-bottomed wells of micro titer plates using 2% (v/v) trypsinized cattle blood erythrocyte suspension [15]. Trypsin inhibitor activity was determined by casein

digestion method, while α -amylase inhibitor activity was measured by using starch as a substrate [16, 17].

Biological value

Sixty 23 days old male albino rats with an initial body weight of 40 ± 5 g were randomly divided into six groups of 10 rats each and housed individually in cages. The rats were maintained at 22°C under 12 h light and 12 h dark cycles at Karpagam Animal House (Approved by Animal Ethical Committee, Government of India). The experimental diets were prepared according to the feed composition described by Chapman *et al.* [18]. The control diet (T1) was prepared by including corn starch (70%), casein (10%), corn oil (10%), non-nutritive cellulose (5%), mineral mixture (4%) and vitamin mixture (1%). The casein protein was replaced by 10% of raw SB seeds, soaked SB seeds, cooked SB seeds, autoclaved SB seeds and roasted SB seeds in the experimental diets T2, T3, T4, T5 and T6, respectively. The experimental animals were subjected to dietary treatments (T1-T6) for 28 days. The feed and water were given *ad libitum* throughout the experimental period and the weight of the feed given and the animals were recorded at regular time intervals. The growth performance of the experimental rats was determined from feed intakes and body weight gain. The Feed Efficiency Ratio (FER) and Protein Efficiency Ratio (PER) were calculated according to the method of Chapman *et al.* [18].

Protein quality

The nitrogen balance studies were conducted for 14 days using seventy male albino rats of 50 ± 5 g body weight. The rats were randomly separated into seven groups of 10 rats each and individually housed in polypropylene metabolic cages. Six groups of rats were fed on the experimental diets T1-T6 (as mentioned in the biological value experiment) and the seventh batch of animals was fed with protein free basal diet (T7) for the determination of endogenous and metabolic nitrogen loss in faeces and urine. After 9 days of acclimatization period, the urine and faeces of the experimental animals were collected separately for five days and the nitrogen content was determined by micro-kjeldahl method [7]. The True Digestibility (TD), Biological Value (BV), Net Protein Utilization (NPU) and Utilizable Proteins (UP) of the experimental diets were determined [19 - 21].

Statistical analysis

The data were subjected to a one-way analysis of variance (ANOVA) and the significance of difference between means at 5% was determined by Duncan's Multiple Range Test (DMRT) using Irristat software (version 3/93). Results were expressed as mean values \pm standard deviations of three separate determinations.

RESULTS

The proximate composition of raw and differentially processed SB seeds is shown in the Table 1. The raw SB seeds contained appreciable levels of protein (28.39%), lipid (7.84%), fiber (8.23%), ash (5.63%) and carbohydrates (49.91%). Among the differentially processed SB seed samples, the autoclaved SB sample possessed higher

levels of nutrient profiles. The effects of various processing methods (soaking, cooking, autoclaving and roasting) on the levels of antinutritional compounds of SB seeds are shown in Table 2. Maximum levels of all the antinutritional compounds in SB seeds were effectively removed by autoclaving treatment.

The growth performance of the rats fed on experimental diets T1-T6 is presented in Table 3. Among the dietary treatments T2-T6, the experimental diet T5 containing autoclaved SB seed sample as a protein source exhibited better growth performance of the animals such as FI (219.16 g), BWG (58.24 g), FER (0.26) and PER (2.66). Similarly, higher levels of protein quality parameters such as TD (73.35%), BV (70.51%), NPU (56.48%) and UP (39.16%) were recorded by the experimental diet T5 containing autoclaved SB seeds as a dietary source of protein, when compared to the experimental diets T2-T6 of the present study (Table 4).

DISCUSSION

The crude protein and lipid content of raw SB seeds (28.39% & 7.84%) was higher when compared to certain common legumes such as *Pisum sativum* (21.9% & 2.34%); *Phaseolus vulgaris* (20.9% & 2.49%); *Cicer arietinum* (18.5% & 6.69%) and *Lens culinaris* (20.6% & 2.15%) [22]. All the common processing methods employed in the present study affected the nutrient profiles of SB seeds at significant level ($p < 0.05$) (Table 1). However, among the differentially processed SB seed samples, the autoclaved sample contained higher levels of nutrients. This is in consonance with that of an earlier report on certain under-utilized legumes such as *Abrus precatorius*, *Mucuna pruriens* var. *utilis* and *Entada scandens* [23 - 25]. It was noted that the substantial reduction of ash content (24%) in the soaked SB seed samples might be due to the increased leaching out of both micro and macro minerals into the soaking medium by the enhanced permeability of the seed coat during soaking treatment.

Among the various processing methods employed, the autoclaving was more effective in reducing the maximum levels of various antinutritional substances such as total free phenolics (91%), tannins (85%), L-Dopa (92%), phytic acid (83%), oligosaccharides such as raffinose (84%), stachyose (66%) and verbascose (83%), haemagglutinating activity (88%), trypsin inhibitor activity (75%) and α -amylase inhibitor activity (65%) (Table 2). Similarly, significant reduction of various antinutritional compounds during autoclaving treatment was reported for *Abrus precatorius*, *Mucuna pruriens* var. *utilis*, *Entada scandens*, *Vigna aconitifolia*, *V. sinensis* and *Bauhinia purpurea* [23 - 27].

The FI value (165.43 g) of animals fed with experimental diet T2 containing raw SB seeds (Table 3) was lower when compared to an earlier report on *Canavalia ensiformis* (225 g) and *C. gladiata* (244 g), but higher than that of vegetable pea (105-120 g) and *Canavalia maritima* (93 g) [28 - 30]. The notable differences among the FI values of the rats fed with experimental diets T2-T6 were probably due to the difference in the protein quality and the levels of antinutritional compounds of the raw and differentially processed SB seeds incorporated as a protein ingredient. Maximum

levels of reduction of various antinutritional substances under autoclaving treatment might be related to higher level of FI value (229 g) in animals fed with autoclaved SB seeds inclusive experimental diet T5.

The BWG value (26.62 g) of the animals fed with diet containing raw SB seeds (Table 3) is in agreement with an earlier report on vegetable pea (23-28%) [29]. Among the experimental diets T2-T6, the diet T5 containing autoclaved SB seeds as a protein source significantly improved the BWG of rats (58%), which appears to be higher when compared to the BWG values reported for pressure-cooked seeds of *Canavalia ensiformis* (28%) and *C. gladiata* (32%) [28]. Incorporation of soaked and cooked SB seeds in the experimental diets T3 and T4, respectively did not have a beneficial effect on the BWG of the rats. It might be due to the presence of higher levels of antinutritional compounds in the SB seeds, which were not destroyed completely by the soaking or cooking treatments.

The lower levels of FER (0.16) and PER (1.61) of the experimental diet T2 (Table 3) might be due to the presence of high concentration of antinutritional substances and poor protein quality of the raw SB seeds included as a protein source. However, these values were higher than that of faba bean (0.032 & 0.32), but lower than that of vegetable pea (0.22 & 2.17) [29, 31]. Among the dietary treatments, the experimental diet T5 containing autoclaved SB seeds resulted in significantly ($p < 0.05$) higher level of FER (0.26) and PER (2.66) values. The PER value of the experimental T5 was found to be higher when compared to *Canavalia ensiformis* (1.24) and *C. gladiata* (1.24) [28]. The results of the present study showed that the higher FI value resulted in higher PER level, which is in good agreement with an earlier report on velvet bean that the PER determination is depended upon feed consumption [24].

Among the dietary treatments, the experimental diets T3 and T4 containing soaked and cooked SB seeds, respectively exhibited lower PER values (1.92 and 2.14, respectively), when compared to the PER level of the experimental diet T5. It might be due to the fact that soaking and cooking treatments were not effective in reducing the antinutritional compounds, which interfered with protein quality of the SB seeds. The lower PER value of the experimental diet T6 containing roasted SB seeds (1.78) was attributed to the formation of protein complexes due to Maillard reaction, which was accelerated by direct heat treatment (roasting) thus resulting into unavailability of proteins for digestion.

PER value below 1.5 describes a protein of poor quality; between 1.5 and 2.0 an intermediate quality and above 2.0, good quality [32]. Hence, the experimental diets T2, T3 and T6 containing raw, soaked and roasted SB seeds, respectively were considered to have a intermediate protein quality, whereas, the experimental diets T4 and T5 containing cooked and autoclaved SB seeds, respectively possess good protein quality.

The TD value (67%) of the experimental diet (T2) containing raw SB seeds was lower compared to the control diet T1 (89%) and other experimental diets T3-T6 (69-79%) of the present study (Table 4), but higher when compared to the TD value of an earlier

report on *Canavalia maritima* (42.2%), *Vicia faba* (63.4%) and comparable with that of vegetable pea (65.8-66.7%) [29 - 31]. The experimental diet T5 containing autoclaved SB seeds exhibited significantly higher level of TD (79%) when compared to the other experimental diets T2-T6 and also an earlier report on the TD level of *Canavalia ensiformis* (76.4%) and *Vicia faba* (71.4%) [28, 31].

The consumption of raw legume seed proteins was reported to increase the endogenous nitrogen loss through the shedding of intestinal mucosa, an effect that reduced the biological value of raw legume seed proteins [33, 34]. Further, the presence of various antinutritional substances, including trypsin inhibitors, which inhibits the complete digestion of proteins and increases the excretion of endogenous faecal nitrogen [23, 24]. These facts may also be partly responsible for the decrease in the TD value of experimental diet T2 containing raw SB seeds as a protein ingredient.

The BV value recorded for the experimental diet T2 (58%) (Table 4) was lower when compared with that of previous reports on vegetable pea (62.9-63.1%) and faba bean (60.4%) [29, 31]. The NPU value of experimental diet T2 (42%) also was lower when compared to control diet T1 (73%) and other experimental diets T3-T6 (46-56%), but higher than that of an earlier report on NPU level of *Canavalia maritima* (16.8%) and *Vicia faba* (38.3%) [30, 31]. The experimental diet T5 containing autoclaved SB seeds exhibited highest level of NPU (56.4%) among the dietary treatments T2-T6, which is in agreement with that of a previous report on velvet bean [24]. The level of UP in experimental diet T2 (26%) was found to be higher than that of an earlier report on UP level of vegetable pea (8.4-8.6%) [29]. Among the dietary treatments T2-T6, the highest level of UP (39%) was registered by the experimental diet T5 containing autoclaved SB seeds as a protein source.

Rats that received casein as a dietary protein source in the experimental diet T1 were able to take advantage of the supplied protein to favour the growth performance, probably as a result of more balanced supply of essential amino acids provided by that diet. In rats fed with experimental diet T2 containing raw SB seeds, a part of the protein supplied might be rerouted for the synthesis of digestive enzymes such as trypsin and chymotrypsin to offset the effects of various antimetabolic substances present in the raw SB seeds. This could have exacerbated the deficiency of sulphur containing amino acids in legume seeds and manifested as a lower production of body tissues [23 - 25]. Hence the experimental diet T2 containing raw SB seeds had poor TD, BV, NPU and UP values.

The protein quality parameters such as TD, BV, NPU and UP of the experimental diet T5 containing autoclaved SB seeds as a protein source was found to be higher than that of other dietary treatments T2-T6 of the present study and also comparable with that of a previous report on the protein quality of *Abrus precatorius*, *Mucuna pruriens* var. *utilis* and *Entada scandens* [23 - 25]. Such a higher level of protein quality of the experimental diet T5 might be attributed to the inclusion of autoclaved SB seeds, in which reduction of higher levels of various antinutrients was noticed in addition to some other factors such as disruption of protein structure during autoclaving

treatment, which might have increased accessibility of SB seed proteins to enzymatic attack.

No such improvement was observed in the protein quality of the experimental diet T6 containing roasted SB seeds, which might be due to the fact that dry heat treatment could have led to formation of isopeptide bonds. This reduced the protein quality, since isopeptides are not hydrolyzed in the intestine because they are resistant to proteolytic enzymes and are thus excreted in faeces [24, 25]. As a result, digestibility and availability of some amino acids were reduced and thus exhibited poor protein quality. It was also observed that the wet heat processing method improved the protein quality of *Cicer arietinum* and *Vigna radiata* to a greater extent than the dry heat treatments [35].

CONCLUSION

Results of the present study indicated that autoclaving was the most effective processing method for maximum reduction in levels of antinutritional compounds of SB seeds without affecting the nutritional quality. When considering the biological value, among the differentially processed SB seed samples, the autoclaved samples included as a protein source in the experimental diet exhibited better animal growth performance and protein quality. Hence, such economic and viable autoclaving treatment could be recommended for the versatile utilization of SB seeds as an alternative/additional and economical source of protein in the diets of human beings/animals, after conducting a long term toxicological evaluation. Exploitation of such potential under-utilized legume grains as a protein ingredient in the food/feed will clearly reduce the over-dependence on common legumes for increasing protein requirements, especially in the developing countries.

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Table 1: Proximate composition of raw and differentially processed sword bean seeds

Proximate composition	Raw seeds	Processed seeds			
		Soaked	Cooked	Autoclaved	Roasted
Moisture ¹	8.14 ^b ± 0.24	8.22 ^c ± 0.15	8.26 ^{cd} ± 0.04	8.29 ^d ± 0.12	7.13 ^a ± 0.20
Crude protein ¹	28.39 ^d ± 0.31	28.04 ^a ± 0.25	28.13 ^b ± 0.17	28.36 ^e ± 0.25	28.25 ^c ± 0.12
Crude lipid ¹	7.84 ^{bc} ± 0.22	7.82 ^{ab} ± 0.08	7.83 ^{bc} ± 0.24	7.85 ^{cd} ± 0.20	7.78 ^a ± 0.15
Crude fiber ¹	8.23 ^d ± 0.17	8.02 ^a ± 0.25	8.08 ^b ± 0.13	8.16 ^c ± 0.22	8.14 ^c ± 0.32
Ash ¹	5.63 ^d ± 0.25	4.28 ^a ± 0.25	4.93 ^b ± 0.30	5.27 ^c ± 0.25	5.62 ^d ± 0.20
NFE ²	49.91 ^a ± 0.02	51.84 ^e ± 0.25	51.03 ^d ± 0.12	50.36 ^c ± 0.10	50.21 ^b ± 0.17
Calorific value (kJ / 100 g DM)	1603 ^a ± 0.14	1629 ^e ± 0.05	1617 ^d ± 0.13	1610 ^c ± 0.06	1604 ^b ± 0.22

Values are mean and standard deviation of three separate determinations.

Values in the same row with different alphabets are significantly different (p<0.05).

¹Values expressed on g/100g sample.

²NFE- Nitrogen Free Extractives expressed on percentage (%) basis.

Table 2: Effect of various processing methods on the antinutritional compounds of sword bean seeds

Antinutritional compounds	Raw seeds	Processed seeds			
		Soaked	Cooked	Autoclaved	Roasted
Total free phenolics ¹	2.16 ^e ± 0.13	1.96 ^d ± 0.26	0.83 ^b ± 0.02	0.19 ^a ± 0.01	0.91 ^c ± 0.21
Tannins ²	75 ^e ± 0.12	56 ^d ± 0.01	27 ^b ± 0.01	24 ^a ± 0.02	42 ^c ± 0.13
L- Dopa ¹	2.63 ^d ± 0.02	1.45 ^c ± 0.02	0.85 ^b ± 0.02	0.22 ^a ± 0.03	0.82 ^b ± 0.31
Phytic acid ²	830 ^e ± 0.23	764 ^d ± 0.02	327 ^b ± 0.02	136 ^a ± 0.05	680 ^c ± 0.06
Raffinose ¹	1.53 ^e ± 0.14	1.10 ^c ± 0.12	0.62 ^b ± 0.17	0.24 ^a ± 0.01	1.31 ^d ± 0.08
Stachyose ¹	1.89 ^d ± 0.19	0.94 ^c ± 0.15	0.86 ^b ± 0.02	0.13 ^a ± 0.04	0.85 ^b ± 0.13
Verbascose ¹	4.53 ^e ± 0.15	3.27 ^d ± 0.43	1.22 ^b ± 0.32	0.76 ^a ± 0.12	3.18 ^c ± 0.15
Haemagglutinating activity ³	74.86 ^e ± 1.41	55.41 ^d ± 1.25	22.76 ^c ± 1.07	8.64 ^a ± 0.15	9.19 ^b ± 0.18
Trypsin inhibitor activity ⁴	47.33 ^e ± 1.52	32.41 ^d ± 2.36	20.02 ^c ± 0.85	11.50 ^a ± 1.04	12.30 ^b ± 1.32
Amylase inhibitors activity ⁵	24.01 ^e ± 0.71	18.26 ^d ± 0.95	13.51 ^b ± 0.73	8.30 ^a ± 0.66	15.12 ^c ± 1.24

Values are mean and standard deviation of three separate determinations.

Values in the same row with different alphabets are significantly different (p<0.05).

¹Values expressed on g/100g sample.

²Values expressed on mg/100 g sample.

³ Values expressed on haemagglutination unit/100 g sample

⁴ Values expressed on trypsin inhibitor unit/100 g sample

⁵ Values expressed on amylase inhibitor unit/100 g sample

Table 3: Growth performance of experimental rats fed on differently processed sword bean (SB) diets as a protein source

Experimental diets	Feed Intake (FI) (g/28 days)	Body Weight Gain (BWG) (g/28 days)	Feed Efficiency Ratio (FER)	Protein Efficiency Ratio (PER)
T1	284.64 ^f ± 0.23	88.29 ^f ± 0.54	0.31 ^f ± 0.17	3.11 ^f ± 0.62
T2	165.43 ^a ± 1.34	26.62 ^a ± 2.16	0.16 ^a ± 0.03	1.61 ^a ± 0.91
T3	183.02 ^b ± 0.34	35.15 ^b ± 0.18	0.19 ^{bc} ± 0.09	1.92 ^c ± 0.52
T4	202.74 ^c ± 3.12	43.38 ^d ± 0.12	0.21 ^{cd} ± 0.06	2.14 ^d ± 0.11
T5	219.16 ^e ± 0.41	58.24 ^e ± 0.67	0.26 ^e ± 0.02	2.66 ^e ± 0.27
T6	212.51 ^d ± 1.53	37.77 ^c ± 0.14	0.18 ^{ab} ± 0.02	1.78 ^b ± 0.31

Values are mean and standard deviation of three separate determinations.

Values in the same column with different alphabets are significantly different (p<0.05).

T1- contains casein as a protein source; T2- contains raw SB seeds as a protein source;

T3- contains soaked SB seeds as a protein source; T4- contains cooked SB seeds as a protein source; T5- contains autoclaved SB seeds as a protein source; T6- contains roasted SB seeds as a protein source.

Table 4: Protein quality (%) of the experimental diets containing raw and differentially processed sword bean (SB) seeds as a protein ingredient

Experimental diets	True Digestibility (TD)	Biological Value (BV)	Net Protein Utilization (NPU)	Utilizable Proteins (UP)
T1	89.47 ^f ± 0.18	82.53 ^f ± 0.21	73.65 ^f ± 0.21	60.38 ^f ± 0.19
T2	67.24 ^a ± 0.32	58.27 ^a ± 0.23	42.83 ^a ± 0.15	26.27 ^a ± 0.16
T3	69.56 ^b ± 0.31	62.44 ^b ± 0.15	46.29 ^c ± 0.13	31.65 ^c ± 0.14
T4	74.81 ^d ± 0.13	65.26 ^d ± 0.02	49.56 ^d ± 0.15	34.42 ^d ± 0.16
T5	79.35 ^e ± 0.12	70.51 ^e ± 0.31	56.48 ^e ± 0.21	39.16 ^e ± 0.62
T6	73.13 ^c ± 0.24	63.49 ^c ± 0.12	44.24 ^b ± 0.14	29.08 ^b ± 0.15

Values are mean and standard deviation of three separate determinations.

Values in the same column with different alphabets are significantly different (p<0.05).

T1- contains casein as a protein source; T2- contains raw SB seeds as a protein source;

T3- contains soaked SB seeds as a protein source; T4- contains cooked SB seeds as a protein source; T5- contains autoclaved SB seeds as a protein source; T6- contains roasted SB seeds as a protein source

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