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Full Paper

Nutritive composition of soybean by-products and nutrient digestibility of soybean pod husk

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Abstract: Soybean by-products (soybean germ, soybean milk residue, soybean hull, soybean pod husk and soybean stem) were subjected to proximate analysis, and in vitro digestibility of DM (IVDMD), ADF (IVADFD) and NDF (IVNDFD) were determined after digesting the by-products in buffered rumen fluid for 24 or 48 h in 2 ANKOM^{II} Daisy Incubators using Completely Randomised Design. Four native cattle (body weight 210 $\pm$ 13.5 kg) were used to determine nutrient digestibility of soybean pod husk. They were randomly assigned by Cross-over Design to receive two roughage sources, i.e. guinea grass and guinea grass + soybean pod husk (60:40 DM basis), in two experimental periods. Guinea grass was harvested on the 35th day after the first cut of the year and used as green forage. Total collection method was used to determine the digestibility coefficients and digestibility by difference was used to calculate nutrient digestibility of soybean pod husk.

The nutritive composition showed that soybean germ was highest in CP content (42.27% of DM) and EE content (5.07% of DM) but lowest in NDF and ADF content (20.09 and 21.53% of DM respectively). The average CP content of soybean straw, soybean stem and soybean pod husk was low (4.91, 4.67 and 5.04% respectively), while ADF content was high (42.76, 38.01 and 42.08% respectively). In vitro digestibility of DM (IVDMD), ADF (IVADFD) and NDF (IVNDFD) showed that all of them, except soybean stem, can be used as cattle feed, e.g. as supplemented feed or admixture in concentrate feed. Digestibility coefficients of guinea grass were higher in CP, CF and EE when compared to the other groups. The apparent digestibility of CP and CF were highly different ($P<0.01$) and that of EE was significantly different ($P<0.05$). No significant difference was found in digestibility of DM, OM and ADF ($P>0.05$). The digestibility of nutrients (DM, OM, CP, CF, NFE, NDF and ADF) of soybean pod husk were 53.81 $\pm$ 4.3, 59.69 $\pm$ 4.6, 42.38 $\pm$ 3.8, 30.71 $\pm$ 3.2, 50.74 $\pm$ 4.3, 75.26 $\pm$ 4.0, 45.78 $\pm$ 3.7 and 30.53 $\pm$ 4.2 % respectively. Soybean pod husk was higher in total digestible nutrients (TDN) (51.87 $\pm$ 3.3 vs.48.75 $\pm$ 3.1 %DM) and digestible energy (DE) (2.11 $\pm$ 0.3 vs. 2.08 $\pm$ 0.2 Mcal/kg.DM) than guinea grass.

Keywords: apparent digestibility, energy value, soybean by-products, soybean hull, soybean straw, soybean pod husk, soybean germ, soybean milk residue, soybean stem

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Introduction

Soybean is one of the major cash crops in Chiang Mai. The products from soybean were usually used as human food and the by-products as animal feed. The harvesting season occurs between March and May, exactly the same time when green forage is short. In the field, soybean straw and soybean pod husk are usually left behind as waste when the seeds have been mechanically or manually harvested and trashed. Soybean straw is a major by-product which is composed of stem, leaf and pod husk. The nutritive value of soybean straw is higher than rice straw but lower than pod husk [4,6]. Therefore, in the dry season it can be well used as alternative or supplemented roughage for cattle both as dry and treated feed even though the crude protein is lower than general roughage. For untreated soybean straw, the palatability is low because of its relative hard stem.

Soybean hull, soybean germ (embryo) and soybean milk residue are by-products from soybean industry which farmers also use for cattle feed, practically as supplemented feed or admixture in feed concentrate. However, only a few studies reported on the nutritive composition and the digestibility of nutrients of these by-products in native beef cattle. Therefore, this experiment is aimed to provide a database on the nutritive composition of soybean by-products, and also on the nutrient digestibility of soybean pod husk.

Materials and Methods

Nutritive composition

Soybean hull, soybean germ and soybean milk residue, which are by-products from soybean industry in Chiang Mai province, were collected and sampled for analysis. To obtain a sufficient and uniform sample, each by-product was repeatedly sampled from several bags and mixed thoroughly before randomly taken for analysis. Soybean straw was collected from ten areas in San Sai district, Chiang Mai. Stem and pod husk were separated and samples were mixed throughly prior to analysis of dry matter (DM), crude protein (CP), crude fiber (CF), ether extract (EE), nitrogen free extract (NFE), calcium (Ca), phosphorus (P), and gross energy (GE) according to the methods described in AOAC [1]. The analysis of neutral detergent fibre (NDF) and acid detergent fibre (ADF) was carried out according to Detergent method [17].

Digestibility study

In vitro digestibility

Dried and ground (1mm) samples of soybean by-products (soybean stem, soybean pod husk, soybean hull, soybean germ (embryo) and soybean milk residue)(Figure 1) were analysed for DM, NDF and ADF. In vitro digestibility of DM (IVDMD), NDF (IVNDFD), and ADF (IVADFD) were determined after incubating the samples in buffered rumen fluid for 24 h and 48 h using ANCOM^{II} Daisy Incubators (ANKOM Technology, Macedon, NY). The buffer was prepared according to the ANKOM Technology procedure. Rumen fluid was obtained before feeding from 2 fistulated native beef cattle fed with guinea grass + soybean pod husk at 60:40 DM basis (1.5-1.9%BW). The experimental design was a completely randomized design.

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Apparent digestibility

Four native beef cattle at three years of age with an average body weight of 210 ± 13.5 kg were randomly allocated to one of the two dietary treatments in 2 experimental periods according to Cross-over Design. The treatments were (1) guinea grass and (2) guinea grass + soybean pod husk at 60:40 DM basis. The roughage was fed to the animal as single feed twice daily at 1.5- 1.9 % of the body weight (DM basis). Water and mineral blocks were freely available throughout the experimental periods. The experiment was conducted at Maejo University during July to September 2007. Soybean pod husks used in this experiment were collected from ten areas in San Sai district, Chiang Mai, and mixed thoroughly prior to use as experimental diet. Guinea grass (*Panicum maximum*) was harvested from the university farm on the 35th day after the first cut of the year. The grass was prepared by chopping to pieces of 2 - 4 cm. long before feeding. Total collection method was assigned for the determination of apparent total tract digestibility of nutrients.

Each digestibility period lasted 21 days with preliminary period taking place in the first 14 days and collection period being in the last 7 days. Feed intake was recorded daily throughout the entire experiment. Roughage DM intake was calculated on DM basis. Feces and leftover feed were collected and used for the calculation of nutrient digestibility. Digestibility by difference was used to calculate nutrient digestibility of soybean pod husk. Total digestible nutrients (TDN) were calculated using the equation: TDN = digestible CP + digestible CF + digestible NFE + digestible EE × 2.25 [10]. Gross energy of feed and feces were determined using adiabatic bomb calorimetre (IKA calorimetre system C 5000). Digestible energy was then calculated. The data were analysed according to Completely Randomised Design and Cross-over Design [13]. The significant differences between the treatments were analysed based on Duncan' new multiple range test [12].

Results and Discussion

Nutritive composition of soybean by-products

The dry matter content of soybean milk residue was lowest among the soybean by-products. This might be due to the cooking method of the seeds during soybean milk processing. The low average CP content and high NDF and ADF content (Table 1) showed that soybean straw, soybean stem and soybean pod husk are not good roughage sources and should not be used as the main roughage for ruminants. However, their nutritive values are higher than rice straw, which are usually used as roughage in the dry season. To improve the nutritive value of soybean straw and soybean pod husk, chemical treatment with urea (fertiliser grade) or spraying with urea molass solution are also suggested [14,15].

Among all by-products, soybean germ was highest in CP content (42.27% of DM) and EE content (5.07% of DM) but lowest in NDF and ADF content (20.09 and 21.53% of DM respectively). Apparently this is because it is the reserve food for germ growth. As for the nutritive composition of soybean hull in this experiment, especially CP content (12.65%), this was comparable to that reported (11.42%) by Gerngang [3]. In practice, the farmers also use soybean germ and soybean hull as supplemented feed or admixture in feed concentrate even though soybean hull are light, flaky and bulky. Soybean milk residue was relatively high in CP and EE content but low in NDF and ADF content when compared with soybean hull (27.88 vs. 12.65%, 4.98 vs. 2.82%, 30.80 vs. 43.79%, and 23.11 vs. 33.66% respectively). Farmers also use soybean milk residue, the soybean seed by-product which is left after the filtration of soybean milk, as supplemented feed for cattle because it contains relatively high content of protein and energy.

Figure 1. By-products from soybean field and soybean industry

Table 1. Chemical composition of soybean by-products used in the experiment

Item	DM (%)	% of DM						GE (kcal/g.DM)
		CP	EE	NDF	ADF	Ca	P	
Soybean straw	89.76	4.91	1.21	54.24	42.76	1.21	0.07	3.90
Soybean stem	93.59	4.67	1.84	56.41	38.01	0.81	0.08	3.86
Soybean pod husk	91.11	5.04	1.65	60.15	42.08	1.21	0.06	3.98
Soybean hull	92.37	12.65	2.82	43.79	48.66	0.55	0.18	4.22
Soybean milk residue	59.96	27.88	4.98	30.80	23.11	0.53	0.37	4.88
Soybean germ	92.19	42.27	5.07	20.09	21.53	0.22	0.70	5.14

In vitro digestibility of soybean by-products

Among the soybean by-products, soybean germ was highest in IVDMD and IVADFD values (P>0.01) at 24 and 48 h, and soybean hull was highest in IVNDFD value (P>0.05) (Tables 2-3). Unlike the other soybean by-products, soybean stem was lowest in IVDMD value (P>0.01) at 24 and 48 h. The increase in IVDMD value at 24 and 48 h in soybean by-products, except soybean stem, suggests that these by-products could be used as feed for ruminants. The in vitro digestibility of nutrients (DM, ADF and NDF) increased with incubation time. The in vitro digestibility of ADF (IVADFD) and NDF (IVNDFD) followed the same pattern as that of DM digestibility. The IVADFD values of the by-products were highly different (P<0.01) while IVNDFD values were

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significantly different (P<0.05) as influenced by the nutritive composition. Fibre digestibility values (IVADFD and IVNDFD) of soybean stem were not found in this in vitro digestibility experiment. Thus, soybean stem is not recommended for ruminant feeding.

Table 2. In vitro DM and fibre digestibility (%) of soybean by-products at 24 h

Item	IVDMD**	IVADFD**	IVNDFD*
Soybean germ	46.83^{A}	27.79^{A}	9.74^{B}
Soybean milk residue	24.77^{B}	8.13^{B}	6.62^{BC}
Soybean hull	26.11^{B}	9.04^{B}	13.16^{A}
Soybean pod husk	27.03^{B}	0.50^{C}	6.75^{BC}
Soybean stem	4.76^{C}	-	-

* Means with different superscripts differ significantly (P<0.05).
** Means with different superscripts differ highly (P<0.01).

Table 3. In vitro DM and fibre digestibility (%) of soybean by-products at 48 h

Item	IVDMD**	IVADFD**	IVNDFD*
Soybean germ	68.95^{A}	58.01^{A}	58.59^{A}
Soybean milk residue	57.03^{B}	38.07^{B}	29.75^{C}
Soybean hull	52.89^{B}	31.71^{B}	38.85^{B}
Soybean pod husk	45.07^{C}	18.79^{C}	28.71^{C}
Soybean stem	6.14^{D}	-	-

* Means with different superscripts differ significantly (P<0.05).
** Means with different superscripts differ highly (P<0.01).

Apparent digestibility of nutrients

The data from the nutritive composition (Table 4) show that guinea grass cut on the 35th day (after the first cut of the year) had a higher nutritive value than soybean pod husk, especially CP, EE, NDF and ADF (10.12 vs. 5.11%, 2.98 vs. 1.79%, 68.82 vs. 58.64%, and 49.64 vs. 41.09% respectively). The crude protein content of soybean pod husk in this experiment was similar to that reported by Cheva-Isarakul et al. [2] and Sruamsiri et al. [16], but was lower than the value reported by Sanitwong et al. [11]. The difference might be attributed to variation in cultivar, cultivation area, water supply and management during their growth, as well as the amount of contained stem or branch particles.

Table 4. Nutritive composition of guinea grass and soybean pod husk

Item	DM	% of DM						GE
	(%)	CP	CF	EE	NFE	NDF	ADF	(kcal/g.DM)
Guinea grass	22.33	10.12	32.68	2.98	42.70	68.82	49.64	3.94
Soybean pod husk	89.96	5.11	35.07	1.79	50.62	58.64	41.09	3.99

It was observed that cattle fed with guinea grass + soybean pod husk consumed slightly lower dry matter than the guinea grass-fed group (3.72 vs. 4.15 kg/h/d which is equal to 1.76 vs. 1.89%BW respectively). This might be due to physical characteristic of soybean pod husk which is bulky and provides less nutrients, especially nitrogen for microbial growth and activities in the rumen. The negative effect of the group fed with guinea grass + soybean pod husk was thus due to the nutritive value of the pod husk, which was low in CP but high in CF content. The result from this experiment agrees with that of Oldham [9], who found that increasing CP content of the diet tended to increase dry matter intake.

Table 5 shows that the digestibility values of CP, CF and EE in cattle fed with guinea grass were higher than those of guinea grass + soybean pod husk group. The apparent digestibility values of CP and CF were highly different (P<0.01) while the digestibility value of EE was significantly different (P<0.05). The result agrees with that of Hoover [5], who reported that fibre digestibility of the diet decreased with increasing fibre intake, and that of Van Soest [18], who found that nutrient digestibility decreased with increased fibre intake. Guinea grass was lower in digestibility of DM, OM, NFE, NDF and ADF than guinea + soybean pod husk. The apparent digestibility of NFE and NDF were highly different (P<0.01). No significant difference was found on the apparent digestibility of DM, OM and ADF (P>0.05). The positive effect of digestibility of DM, OM, NFE, NDF and ADF in the group fed with guinea + soybean pod husk was due to the pod husk being lower in cell wall and lignin content (ADF) than guinea grass. Lignin is an undigestible cell wall component in plant and feedstuff, thus tending to limit nutrient digestibility especially of carbohydrate components [7,8].

Table 5. Apparent digestibility of guinea grass and guinea grass + soybean pod husk (60:40)

	Apparent digestibility (%)	
Nutrient	Guinea grass	Guinea grass + Soybean pod husk (60:40)
DM	52.21 ± 4.8	53.28 ± 5.1
OM	51.83 ± 4.2	53.29 ± 4.8
CP**	62.99^{A} ± 2.4	57.19^{B} ± 2.2
CF**	40.88^{A} ± 4.2	33.26^{B} ± 4.8
EE*	68.22^{A} ± 3.2	55.32^{B} ± 2.4
NFE**	46.55^{B} ± 4.2	65.48^{A} ± 3.3
NDF**	41.42^{B} ± 4.4	48.43^{A} ± 4.1
ADF	38.16 ± 3.8	39.53 ± 4.6

* Means with different superscripts differ significantly (P<0.05).
** Means with different superscripts differ highly (P<0.01).

The results of nutrient digestibility of soybean pod husk calculated by different methods showed that it was high in digestibility of DM, OM, NFE and NDF, but low in that of CP, CF and ADF (Table 6). Calculated TDN from the equation showed that soybean pod husk was higher in the average value of TDN than guinea grass (51.87 ± 3.3 vs. 48.75 ± 3.1%). The digestible energy (DE) content of soybean pod husk in native cattle was 2.11 ± 0.42 Mcal/kg DM (Table 7).

Table 6. Apparent digestibility of nutrients in soybean pod husk

Nutrient	Apparent digestibility, %
DM	53.81 ± 4.3
OM	59.69 ± 4.6
CP	42.38 ± 3.8
CF	30.71 ± 3.2
EE	50.74 ± 4.3
NFE	75.26 ± 4.0
NDF	45.78 ± 3.7
ADF	30.53 ± 4.2

Table 7. Total digestible nutrients (TDN) and digestible energy (DE) of guinea grass and soybean pod husk

Item	TDN (% of DM)	DE (Mcal / kg DM)
Guinea grass	48.75 ± 3.1	2.08 ± 0.3
Soybean pod husk	51.87 ± 3.3	2.11 ± 0.4

Conclusions

The nutritive composition analysis of soybean by-products showed that those from the field, i.e. soybean straw, soybean pod husk and soybean stem, were low in CP and high in CF and ADF content, while by-products from soybean industry, i.e. soybean germ, soybean milk residue and soybean hull, were high in CP but low in NDF and ADF. In vitro digestibility of DM (IVDMD), ADF (IVADFD) and NDF (IVNDFD) showed that all of them, except soybean stem, can be used as cattle feed in the form of supplemented feed or admixture in feed concentrate (soybean hull, soybean germ and soybean milk residue), or supplemented roughage (soybean pod husk and soybean straw).

The digestibility coefficients of DM, OM, CP, CF, NFE, NDF, and ADF of guinea grass were 52.21 ± 4.8, 51.83 ± 4.2, 62.99 ± 2.4, 40.88 ± 4.2, 68.22 ± 3.2, 46.55 ± 4.2, 41.42 ± 4.4, and 38.16 ± 3.8% respectively. Calculation by different methods showed that guinea grass was high in digestibility of CP and EE but low in NDF and ADF. The digestibility coefficients of DM, OM, CP, CF, NFE, NDF, and ADF of soybean pod husk were 53.81 ± 4.3, 59.69 ± 4.6, 42.38 ± 3.8, 30.71 ± 3.2, 50.74 ± 4.3, 75.26 ± 4.0, 45.78 ± 3.7, and 30.53 ± 4.2% respectively. Soybean pod husk was high TDN and DE content when compared to guinea grass (51.87 ± 3.3 vs. 48.75 ± 3.1% and 2.11 ± 0.4 vs. 2.08 ± 0.3 Mcal/kg DM respectively).

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