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In Sacco Degradation Characteristics of Protein Feed Sources in Brahman-Thai Native Crossbred Steers

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ABSTRACT

The nutritive value of six protein feed sources were determined using the nylon bag technique in rumen fistulated Brahman-Thai native crossbred steers. The steers were fed 0.5% BW of concentrate and rice straw *ad libitum*. Nylon bags containing 5.0 g of each feed were immersed in duplicate at each time point in the ventral rumen of each steer for 2, 4, 6, 12, 24 and 48 h. The data were fitted to the equation $P = a+b\ (1-e^{-ct})$ and effective degradability was calculated using a theoretical rumen out flow rate of k = 0.05/h. The treatments were 1) kapok seed meal, 2) soybean meal, 3) coconut meal (solv-extd), 4) peanut meal, 5) whole cotton seed and 6) fish meal assigned according to a completely randomize design with four replications. The results indicate that the rapidly soluble fraction (*a*), potentially degradable fraction (*b*), degradation rate (*c*) and potential degradation (*a*+*b*) of DM, OM and CP were different among treatments ($P < 0.01$). Effective degradability of DM, OM and CP calculated as a percentage of the nutrient were ranked from high to low: DM degradability: soybean meal (60.96%), peanut meal (52.02%), whole cotton seed (47.35%), coconut meal (solve-extd) (42.52%), fish meal (42.37%) and kapok seed meal (24.31%); OM degradability: soybean meal (59.74%), peanut meal (52.17%), whole cotton seed (46.35%), fish meal (46.22%), coconut meal (solv-extd) (39.93%), and kapok seed meal (28.69%); CP degradability: whole cotton seed (74.17%), kapok seed meal (68.18%), fish meal (47.32%), soybean meal (46.42%), peanut meal (45.35%) and coconut meal (solv-extd) (32.61%). The data provids information on combinations of energy and protein sources with similar ruminal degradation, and thus may lead to improved feeding values for ruminants.

Key words: *In sacco* - Protein feed source - Rumen degradation

INTRODUCTION

Ruminal degradation of feed protein is an important factor when assessing the value of protein feed according to the modern ruminant feed evaluation system (1). Woods et al (2) also suggested that there is a requirement to measure the ruminal degradability of different samples of concentrate feedstuffs. The nylon bag technique is widely used to estimate the degradation of feed in rumen. Many reports have been published on the degradability of feedstuffs in ruminant (2,3,4,5,6). Recently, rumen kinetics of digestion are of interest, because the parameters of digestion also characterize the intrinsic properties of feeds that limit their availability to the ruminant (7,8). Promkot and Wanapat (6) investigated ruminal degradation and intestinal digestion of crude protein in tropical protein feed. They found that soybean meal and leucaena leaf meal were highly degraded in the rumen, while cassava hay, cotton seed meal and dried brewers grain were less degraded.

There is very little information available on degradation characteristics of tropical protein feed. Therefore, the objective of this study was to provide a broader base of information concerning degradation characteristics of tropical protein feed sources.

MATERIALS AND METHODS

Feedstuffs Preparation and Analysis

The feedstuffs namely, 1) kapok seed meal, 2) soybean meal, 3) coconut meal (slov-extd), 4) peanut meal, 5) whole cotton seed and 6) fish meal were collected from various feed mills and organizations in the North East of Thailand. All test feed samples **(Table 1)** were ground to pass through a 1 mm screen for nylon bag incubation and chemical analysis. The feedstuffs were analyzed for dry matter (DM), crude protein (CP) and ash content (9). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were assayed by the method proposed by Van Soest et al (10).

Table 1. Chemical composition of various protein feed source (Means ±SD).

Feedstuffs[1]	**DM (%)**	**CP**	**Ash**	**NDF**	**ADF**	**ADL**
		………..…………….% DM basis...………………………				
KM	91.01±0.11	28.09±0.06	8.91±0.07	42.50±0.07	29.49±0.55	16.34±0.01
SM	91.31±0.03	47.24±0.33	7.12±0.01	12.84±1.15	8.26±0.16	0.10±0.002
CMS	86.01±0.01	24.69±0.90	8.59±0.10	80.80±2.17	43.45±0.83	7.94±1.28
PM	92.24±0.07	40.79±0.04	8.72±0.02	28.22±1.24	13.25±0.72	4.95±0.13
WCS	92.64±0.23	21.75±0.02	3.86±0.04	52.28±0.82	37.80±0.27	11.67±0.39
FM	90.01±0.10	61.89±0.52	27.84±0.01	-	-	-

Note: DM = dry matter, CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin

[1]KM = kapok seed meal, SM = soybean meal, CMS = coconut meal (solv-extd), PM = peanut meal, WCS = whole cotton seed, and FM = fish meal

In Sacco Degradation Procedure

Ruminal degradation measurements using the nylon bag technique were carried out in 2 Brahman-Thai native crossbred steers after a two-week adaptation period. The steers with an average body weight of 250±15 kg and fitted with permanent rumen cannula were offered rice straw *ad libitum* and received concentrate at 0.5% BW (concentrate mixture: 49.8% cassava chip, 17.5% rice bran, 14.6% palm meal, 7.0% soybean meal, 1.4% urea, 0.4% salt, 1.0% mineral mix and 8.3% sugarcane molasses). Approximately 5.0 g (as fed basis) of each test feed was accurately weighed into a synthetic bag with a mean pore size of 45 μm (11). Bags plus the samples, were placed into the rumen of two beef steers 30 min after the morning meal and retrieved after the period of 2, 4, 6, 12, 24 and 48 h (four bags of each feed for each period). After removal from the rumen, bags were washed by hand under tap water until the water became clear. After washing, the bags were placed into a hot dry air force oven at 65°C for 48 h and weighed. To determine the content of water soluble material, bags representing 0 h degradation also underwent the same washing procedure as the incubated bags. Dried residues from 4 bags of each incubation time from each steer were pooled; DM, OM and CP were analyzed; then DM, OM and CP disappearance values were calculated as the difference between weight of nutrients before and after incubation of each sample. The degradability data obtained for DM, OM and CP for each feed were fitted to the equation $P = a+b\ (1-e^{-ct})$ (12). The effective degradability (ED) was calculated as $ED = a+\{(bc)/(c+k)\}$, where k = fractional passage rate (0.05/h), *a* = rapidly soluble fraction, *b* = potentially degradable fraction, *c* = rate of degradation of *b* fraction (12).

Statistical Analysis

All data obtained were subjected to the analysis of variance (ANOVA) procedure according to the Completely Randomized Design using the general linear method (GLM) of the SAS system (13). Treatment means were compared using Duncan's New Multiple Range Test (14).

RESULTS AND DISCUSSION

Chemical Composition of Protein Feed Source

Chemical compositions of protein feed sources are presented in **Table 1**. Generally, wide variations existed in the chemical composition of the investigated feedstuffs. The CP content of soybean meal was similar to the reports of NRC (1) but higher than the Department of Livestock Development (DLD) (15), Promkot and Wanapat (6), and lower than Woods et al (2). The NDF and ADF content were lower than those reported by the NRC (1) and DLD (15), but similar to Woods et al (2), Promkot and Wanapat (6).

The CP content of coconut meal (slov-extd) was higher than that of Ibrahim et al (16), DLD (15) and Woods et al (2). The NDF and ADF contents were higher than those reported by Ibrahim et al (16) but the ADF content was similar to that of Woods et al (2).

The CP content of peanut meal was lower than NRC (1) and DLD (15) while the NDF was higher but the ADF was in agreement with that reported by the DLD (15).

The CP content of whole cotton seed was higher than that reported by DLD (15), but similar to NRC (1). In addition the NDF, ADF and ADL contents were also similar to NRC (1).

The CP content of fish meal was lower than Harstad and Prestlokken (17), but similar to NRC (1) and DLD (15).

This study indicated that fish meal CP content was the highest among protein feed sources in this study. Whole cotton seed was shown to have the lowest CP content. Coconut meal (solv-extd) had the highest NDF and ADF content as compared to other protein feed sources. Soybean meal showed the lowest NDF, ADF and ADL content. Many factors affect the chemical composition of feeds such as oil extraction process (18), stage of growth (6), maturity, species or variety (19,20), drying method, growth environment (21) and soil types (22). These factors may partially explain the differences in chemical composition between our study and others.

Degradability Characteristics

The rapidly soluble fraction (*a* fraction), potentially degradable fraction (*b* fraction), rate of degradation of *b* fraction (*c*) and potential degradation (*a*+*b*) are presented in **Table 2**. Dry matter *a* fraction was highest ($P < 0.01$) in whole cotton seed and lowest in kapok seed meal. This value in soybean meal was lower than those reported by Batajoo and Shaver (23), Wulf and Sudekum (24) but was similar to previous reports of Tuncer and Scakli (25), Promkot and Wanapat (6). In addition, this value in coconut meal (solv-extd) was lower than that reported by Woods et al (2).

Organic *a* fraction was highest in whole cotton seed ($P < 0.01$) and lowest in kapok seed meal. However this value in coconut meal was lower than that reported by Ibrahim et al (16) and Woods et al (2). In addition, this value in soybean meal was lower than that reported by Woods et al (2) but similar to Tuncer and Scakli (25).

Crude protein *a* fraction was highest in whole cotton seed ($P < 0.01$) and lowest in kapok meal. In fish meal it was lower than that reported by Chiou et al (26). While in soybean meal if was lower than those reported by Batajoo and Shaver (23), Promkot and Wanapat (6). However, crude protein *a* fraction of soybean meal was similar to the report by Woods et al (2) and Tuncer and Scakli (25) and in coconut meal (solv-extd).

The soluble fractions make the feed easily attachable by ruminal microorganisms and lead to higher degradation. This study indicated that whole cotton seed, peanut meal and soybean meal were easily attachable by ruminal microorganisms, because of their higher soluble faction when compared to the other feeds in this experiment **(Table 2)**. Variation in this fraction between studies could be due to the differences in feed particle size and the processing methods (i.e. degree of heating) or differences in analytical technique (23). In the present study, feeds were ground to 1 mm, which may have contributed to a higher soluble fraction observed in some feeds. However, some studies have shown that feed particle size does not affect the rate of DM and N degradation in some studies (27). Additionally, animal species (cow vs sheep) do not affect rate and extent of DM degradation (28).

The dry matter *b* fraction for all feeds ranged from 32.95 to 74.15%. Dry matter *b* fraction was similar for soybean meal, coconut meal (solv-extd) and peanut meal. That of soybean meal was higher than those reported by Batajoo and Shaver (23), Woods et al (2), Promkot and Wanapat (6), and Wulf and Sudekum (24). However, this value was similar to the previous report of Tuncer and Scakli (25). This value in coconut meal (solv-extd) was higher than that reported by Woods et al (2). In this study, *b* fraction was highest in soybean meal and lowest in fish meal. The result agrees with that reported by Promkot and Wanapat (6).

Table 2. *In sacco* degradation characteristics and effective degradability of protein feed source.

Parameters	Treatment[1]						SEM
	KM	SM	CMS	PM	WCS	FM	
DM degradation							
a, %	7.72[d]	25.85[b]	17.49[c]	23.40[b]	32.54[a]	23.87[b]	1.70
b, %	37.86[b]	74.15[a]	71.25[a]	62.61[a]	42.66[b]	32.95[b]	4.17
c, %/h^{-1}	0.039[ab]	0.045[ab]	0.028[b]	0.056[ab]	0.032[b]	0.065[a]	0.01
a+*b*, %	45.59[d]	100.0[a]	88.68[ab]	86.02[ab]	75.21[bc]	56.82[dc]	4.78
EDDM, %	24.31[c]	60.96[a]	42.52[b]	52.02[ab]	47.35[b]	42.37[b]	2.96
OM degradation							
a, %	12.32[c]	24.25[b]	13.55[c]	23.53[b]	31.65[a]	30.54[a]	1.86
b, %	36.35[b]	75.75[a]	78.95[a]	64.02[a]	48.23[b]	37.08[b]	3.98
c, %/h^{-1}	0.057[a]	0.044[b]	0.025[c]	0.049[b]	0.027[c]	0.057[a]	0.01
A+*b*, %	48.67[d]	99.90[a]	92.92[ab]	87.53[ab]	79.91[bc]	67.63[c]	4.23
EDOM, %	28.69[e]	59.74[a]	39.93[d]	52.17[b]	46.35[c]	46.22[c]	2.06
CP degradation							
a, %	10.22[d]	10.98[d]	16.01[c]	15.14[c]	37.68[a]	27.85[c]	2.33
b, %	61.80[b]	89.02[a]	65.38[b]	84.86[a]	46.60[c]	36.40[c]	4.15
c, %/h^{-1}	0.264[a]	0.038[c]	0.017[c]	0.028[c]	0.181[b]	0.058[c]	0.02
A+*b*, %	72.02[b]	100.0[a]	81.39[b]	100.0[a]	84.28[b]	64.25[c]	3.89
EDCP, %	62.18[b]	46.42[c]	32.61[d]	45.35[c]	74.17[a]	47.32[c]	2.71

[a, b, c, d] Means within a row with different superscripts differ ($P < 0.01$)
[1]KM, SM, CMS, PM, WCS, FM, DM, OM, and CP see **Table 1**, *a,b,c* are constants in the exponential equation $P = a+b(1-e^{-ct})$, EDDM = effective degradability of dry matter, EDOM = effective degradability of organic matter, EDCP = effective degradability of crude protein, *a* = the rapidly soluble fraction, *b* = the potentially degradable fraction, *c* = the rate of degradation of fraction *b*, *a*+*b* = potential degradation

The organic matter *b* fraction was high in coconut meal (solv-extd), soybean meal but low in kapok meal, whole cotton seed and fish meal. Similar organic matter *b* fraction was also observed in coconut meal (solv-extd) and peanut meal. This value in coconut meal was higher than those reported by Ibrahim et al (16) and Woods et al (2) and that of soybean meal was higher than Woods et al (2) but similar to Tuncer and Scakli (25).

The crude protein *b* fraction was highest in soybean meal and lowest in fish meal. That of fish meal was higher than that reported by Chiou et al (26) but soybean meal was higher than that of Batajoo and Shaver (23) and Promkot and Wanapat (6) and was similar to Tuncer and Scakli (25) and Woods et al (5). The potential degradable fraction (*b*) point to degradability of feedstuffs at time "t". Soybean meal, coconut meal and peanut meal had the highest potential degradable fraction. It implies that the structure can be easily attachable by rumen microorganisms, leading to high degradability.

Degradation rate (*c*) of dry matter was fastest ($P < 0.01$) in fish meal followed by peanut meal, kapok seed meal and soybean meal while coconut meal was the slowest. This value in soybean meal was lower than that reported by Promkot and Wanapat (6) Woods et al (2) and Wulf and Sudekum (24) but similar to the reported by Batajoo and Shaver (23). Dry matter degradation rate of coconut meal (solv-extd) was slower than Woods et al (2).

Kapok seed meal and fish meal had the fastest degradation rate of organic matter. The value for soybean meal was similar to peanut meal and coconut meal (solv-extd). However, the value for coconut meal (solv-extd) in this study was slower than that of Ibrahim et al (16) and Woods et al (2) and of soybean meal was lower than Woods et al (2).

The fastest crude protein degradation was observed in kapok seed meal followed by whole cotton seed. That of soybean meal was lower than that reported by Batajoo and Shaver (23), Woods et al (5), Promkot and Wanapat (6) and Wulf and Sudekum (24). Additionally, the degradation rate of crude protein in coconut meal (solv-extd) was lower than that reported by Woods et al (5) and that of fish meal was lower than Chiou et al (26). The rate of degradation (*c*) is as important as the potential degradability in determining both effective degradation as well as rumen fill and also exerts a direct effect on intake (29) which represents the nutrient availability of forages. Matching rate and extent of OM and CP degradability is also a strategy that has been used to maximize the ruminal microbial protein production.

The potential degradation (*a*+*b*) of dry matter, was highest ($P < 0.01$) for soybean meal and lowest for kapok seed meal. The results agree with Promkot and Wanapat (6) who found this value of soybean meal was higher than other tropical protein feed and was similar to the report of Woods et al (2), Tuncer and Scakli (25) and Wulf and Sudekum (24). Additionally, the potential degradation of dry matter for coconut meal (solv-extd) was similar to that reported by Woods et al (2).

The potential degradation of organic matter is the same as that of dry matter for all feeds. The value for coconut meal (solv-extd) was similar to that of Ibrahim et al (16). Additionally, the potential degradation of crude protein in soybean meal was similar to peanut meal, coconut meal (solv-extd) and whole cotton seed. The results agreed with those of Tuncer and Scakli (25) and Woods et al (5), who found that the value in soybean meal was 99% and 95%, respectively. Kapok seed meal had lower ($P < 0.01$) potential degradation of DM, OM and CP than the other protein feed sources. This result might have been reflected by the high level of lignin present **(Table 1)**.

There were high variations of *in sacco* degradability characteristics of protein feed sources. The numerous factors that effect these values are as, bag pore size (30), sample size (27), washing procedures (31), grinding, diet of dornor animals, species of animal, sample preparation, incubation time and washing method (32). The extraction process of oil seed affected all degradation fractions and degradation rate of dry matter and crude proteins (1,23). Furthermore, chemical composition and processing of feedstuffs affected the degradation characteristics (28). Vitti et al (33) also reported that *in sacco* dry matter disappearance was highly correlated, negatively with NDF but positively with phenolic compounds and reducing sugars. These factors may partially explain the differences in kinetic measurements between our study and others.

The potential degradation of protein feed source ranked from highest to lowest were: soy bean meal, coconut meal, peanut meal, whole cotton seed, fish meal and kapok seed meal. However, at present soybean meal is commonly used extensively as non-ruminant feed, thus other protein feed sources should be considered. Moreover, the data base has the advantage to be used in synchronizing the rate of energy and nitrogen release in the rumen to improve ruminal fermentation and microbial protein synthesis (34). Feed with similar ruminal availabilities of crude protein and organic matter could be use in synchronizing nutrient supply for maximum microbial protein in ruminant (35).

Effective Degradability

The effective degradability of DM, OM and CP are also presented in **Table 2**. Rate of passage (k) was assumed to be 0.05/h for calculation of effective degradability (12). The effective degradability of DM, OM and CP was significantly affected by sample of feed used for all the protein feed source ($P < 0.01$). Soybean meal and kapok seed meal had the highest and lowest effective degradability of dry matter, respectively. Promkot and Wanapat (6) reported lower effective degradability of dry matter for soybean meal than reported in this experiment. Additionally, effective degradability of dry matter for soybean meal was lower than those reported by Woods et al (2) and Wulf and Sudekum (24). However, effective degradability of dry matter for soybean meal was similar to that reported by Tuncer and Scakli (25). The effective degradability of dry matter for coconut meal was lower than that reported by Woods et al (2).

The effective degradability of organic matter was highest for soybean meal and lowest for kapok seed meal. Moreover, similar effective degradability of organic matter was observed in whole cotton seed and fish meal. The effective degradability of organic matter for soybean meal was lower than that reported by Woods et al (2). Moreover effective degradability of organic matter for coconut meal was lower than that reported by Ibrahim et al (16) and Woods et al (2).

The effective degradability of crude protein was highest in whole cotton seed followed by kapok seed meal. Whereas, effective degradability of crude protein for soybean meal, peanut meal and fish meal were similar. Crude protein from coconut meal was least effectively degraded indicating that over half of the protein would pass to the small intestine. Other researchers have reported higher effective degradability for soybean meal than this report (5,6,24,26). However, effective degradability of crude protein for soybean meal was in close agreement with Tuncer and Scakli (25). Additionally, the NRC (36) reported effective degradability of crude protein for soybean meal was ranked from 18-86%. The different might have been the degree of heating during the oil extraction process. The effective degradability of crude protein for coconut meal was lower than that reported by Woods et al (5), but in close agreement with the results of Ibrahim et al (16). Effective degradability of crude protein for fish meal was lower than that reported by Chiou et al (26), but in close agreement with the NRC (36). The coconut meal, peanut meal, and fish meal have relatively low rumen degradability, indicative of being a good source of by pass protein.

There are numerous factors that affect effective degradability of crude protein such as the proportion of NPN and true protein and physical and chemical characteristics of true protein (6). Heat treatment during the oil extraction process also affected the effective degradability of crude protein (1). Variation in ruminal protein degradation can be used in two ways, either to maximize substrate available for microbial growth and protein synthesis, or to enhance the intestinal amino acid supply.

CONCLUSIONS

The result of this study demonstrated that protein feed source varied widely in their ruminal DM, OM and CP degradation characteristics. Soybean meal, peanut meal and coconut meal were highly degraded in the rumen, while fish meal, whole cotton seed and kapok seed meal were less degraded. This study provides information on combinations of energy and protein sources with similar ruminal degradation, and thus should lead to improvements in their feeding values for ruminants.

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บทคัดย่อ

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การประเมินคุณลักษณะการย่อยสลายในกระเพาะหมักของแหล่งอาหารโปรตีนในโคลูกผสมบราห์มันโดยใช้ถุงไนล่อน

นำวัตถุดิบอาหารโปรตีนจำนวน 6 ชนิด คือกากเมล็ดนุ่น กากถั่วเหลือง กากมะพร้าว กากถั่วลิสง เมล็ดฝ้าย และปลาป่น มาทำการประเมินคุณค่าทางโภชนะโดยใช้เทคนิคถุงไนล่อน โดยทดลองในโคเนื้อลูกผสมบราห์มันพื้นเมืองเพศผู้ตอน 2 ตัว ให้โคได้รับอาหารข้น 0.5 เปอร์เซ็นต์ของน้ำหนักตัวและได้รับอาหารหยาบคือฟางข้าวแบบเต็มที่ นำวัตถุดิบอาหารแต่ละชนิดมาบรรจุในถุงไนล่อนปริมาณ 5.0 กรัม แล้วจุ่มในกระเพาะหมัก เป็นเวลา 2 4 6 12 24 และ 48 ชั่วโมง ทำ 4 ซ้ำ นำข้อมูลที่ได้ไปคำนวณหาค่าคงที่โดยสมการ $P = a+b\ (1-e^{-ct})$ และนำค่าที่ได้ไปคำนวณหาค่าความสามารถในการย่อยสลายในกระเพาะหมักโดยใช้อัตราการไหลผ่านที่ 5 เปอร์เซ็นต์ต่อชั่วโมง วางแผนการทดลองแบบสุ่มบูรณ์ ผลการทดลองพบว่า ส่วนที่สามารถย่อยสลายได้ง่าย ส่วนที่มีศักยภาพในการย่อยสลาย อัตราการย่อยสลายของส่วนที่มีศักยภาพในการย่อยสลาย และ ศักยภาพในการย่อยสลาย ของวัตถุแห้ง อินทรียวัตถุ และโปรตีน มีความแตกต่างอย่างมีนัยสำคัญยิ่งทางสถิติ ($P < 0.01$) ค่าความสามารถในการย่อยสลายของวัตถุแห้ง อินทรีย์วัตถุ และโปรตีน เมื่อเรียงลำดับจากสูงไปต่ำได้ผลดังนี้คือ ความสามารถในการย่อยสลายของวัตถุแห้ง ได้แก่ กากถั่วเหลือง (60.96%) กากถั่วลิสง (52.02%) เมล็ดฝ้าย (47.35%) กากมะพร้าวสกัดน้ำมัน (42.52%) ปลาป่น (42.37%) และกากเมล็ดนุ่น (24.31%) ความสามารถในการย่อยสลายของอินทรีย์วัตถุ ได้แก่ กากถั่วเหลือง (59.74%) กากถั่วลิสง (52.17%) เมล็ดฝ้าย (46.35%) ปลาป่น (46.22%) กากมะพร้าวสกัดน้ำมัน (39.93%) และกากเมล็ดนุ่น (28.69%) ความสามารถในการย่อยสลายของโปรตีน ได้แก่ เมล็ดฝ้าย (74.17%) กากเมล็ดนุ่น (68.18%) ปลาป่น (47.32%) กากถั่วเหลือง (46.42%) กากถั่วลิสง (45.35%) และ กากมะพร้าวสกัดน้ำมัน (32.61%)

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