Intake, Rumen Degradation and Utilisation of Urea-Ammoniated Grass Hay by Kacang Goats as Affected by Supplementation of Sun-dried Fish or Fishmeal

IGN Jelantik[1)*], MR Weibsjerg[2)] and J Madsen[3)]

[1)] Faculty of Animal Science, The University of Nusa Cendana, Jl. Adisucipto Penfui, Kupang NTT, 85001,
[2)] Department of Animal Health and Bioscience, University of Aarhus, Denmark
[3)] Department of Large Animal Sciences, University of Copenhagen, Denmark
Corresponding author email: jelantikgustingurah@yahoo.com

Abstract. Six mature male Kacang goats were involved in an experiment arranged following a duplicate 3 x 3 Latin Square Design. The objectives of this experiment was to study the effect of supplementation of dried fish as compared to fishmeal on intake, digestion, rumen environment and nitrogen used by the local meat type Kacang goats maintained on urea-treated low quality grass hay. The treatments were G: goats were fed with ad libitum access of urea treated grass hay and 100 g/d *putak*, SDF: G plus 18.4 g sun dried fish, and FM: G plus 19.7 g/d fishmeal. The supplement in SDF and FM were at equal CP level. Intake of urea treated grass hay tended to increase (P=0.08) with supplementation. Dry matter digestibility particularly that of CP was improved by supplementation. Rumen environment was slightly modified by supplementation. Rumen pH was reduced while ammonia concentration was increased. Rumen degradation of the treated grass hay did not differ when incubated in the rumen of goats with different diets. Nitrogen balance was significantly improved (P<0.05) by fishmeal supplementation. In all parameters measured in this experiment, the incremental effects did not differ between fishmeal type. This indicate that there is no further advantage of preparing fishmeal other than sun-drying in improving the utilisation of low quality urea-treated grass hay.

Keywords: kacang goats, fishmeal, intake, digestion, utilisation, rumen environment

Abstrak. Enam kambing Kacang jantan dewasa digunakan dalam eksperimen dengan Rancangan Bujur Sangkar Latin 3x3. Tujuan penelitian adalah menganalisa pengaruh suplementasi ikan kering dibandingkan dengan tepung ikan terhadap asupan, pencernaan, lingkungan rumen dan nitrogen yang digunakan oleh kambing Kacang pedaging lokal yang diberi pakan rumput jerami dengan kandungan urea rendah. Perlakuannya adalah G: kambing diberi pakan ad libitum terdiri dari rumput mengandung urea dan 100 g/d *putak*, SDF: G ditambah 18,4 g ikan kering, dan FM: G ditambah 19,7 g/d tepung ikan. Suplementasi SDF dan FM sama pada level CP l. Asupan rumput yang mengandung urea cenderung meningkat (P<0.05) dengan suplementasi tepung ikan. Pada semua parameter yang diukur dalam penelitian ini, pengaruh antar jenis tepung ikan tidak berbeda. Hal ini menunjukkan bahwa tidak ada keuntungan menyiapkan tepung ikan, melainkan hanya ikan kering yang meningkatkan penggunaan rumput yang mengandung urea.

Kata kunci: kambing kacang, tepung ikan, asupan, pencernaan, penggunaan, lingkungan rumen

Introduction

Low quality mature grass is the predominant feed resource available during the extended dry season for ruminant animals in The Province of Nusa Tenggara Timur. Its nutritive value for ruminant animals is generally low which is comparable to cereal straws (Jelantik, 2001). Consequently, ruminant animals including Kacang goats raised on such grass alone commonly undertake excessive weight losses during the dry season. Therefore, attempts should be made to improve intake and digestibility of such mature grass hay if improved productivity is to be achieved.

Improved intake and digestibility and hence animal production are often reported with urea-treatment on cereal straws as well as other low quality roughage (Vadiveloo and Fadel, 2009). Urea treatment commonly increased crude protein (CP) and reduced neutral detergent fibre (NDF) content resulting higher utilisation of urea-treated low quality forages for low level of productivity (Oji et al., 2007; Ramirez et al., 2007; Suwandyastuti and Bata, 2010). Due to the similar nature of cell walls, similar effect of urea treatment would be expected to occur with mature tropical grass hay.

For moderate level of production, however, further supplementation is required especially with those of true protein such as fishmeal (Jelantik, 2001) or coconut cake (Jelantik and Belli, 2010). The superiority of fishmeal particularly over urea as well as other protein sources to improve the utilisation of low quality forages is often assumed as a result of high content of protein escape which improves non-ammonia nitrogen (NAN) flow from the rumen (Hussein, 1991). In the island of Timor, however, fish is traditionally sun dried without any heat treatments. As a result, it is degraded extensively in the rumen (i.e. 64%. Jelantik, 2001). Yet, its efficacy as a good supplement to low quality forages has been shown in some experiments. The intake of low quality grass hay was significantly increased by sun dried fishmeal supplementation (Jelantik *et al*., 2010a). In a number of experiments, sun-dried fish has been utilised as the main source of protein in calf supplement. Calf supplementation containing sun-dried fish has successfully reduced mortality rate of Bali calves (Jelantik et al., 2008) and increased body weight gain (Jelantik et al., 2010b; Copland et al., 2011) and linear measurements (Leo-Penu et al., 2008). It is therefore questionable whether there is still further advantage of treating fishmeal as compared to sun-dried especially in improving the utilisation of urea-treated low quality tropical grass hay. The present experiment was designed to investigate the effect of supplementation of traditionally sun-dried fish as compared to “conventional” fishmeal where heat-treatment was applied when preparing fishmeal to reduce rumen protein degradation on intake and the utilisation of urea treated tropical grass hay. Hence, the study may locate whether the commonly reported positive response obtained from the supplementation of fishmeal is due to its effect on rumen fermentation or as bypass protein. In addition, this experiment also has practical reason whether further heat treatment on raw fish is needed to supplement low quality grass.

Materials and Methods

Animals, Rations and Experimental design

Six mature male Kacang goats weighing in average 11.6 kg, three of them were fitted with rumen fistula, were used in this experiment. They were placed individually in metabolism cages equipped with facilities for collecting faeces and urine. The experimental design was a replicated (double) 3x3 Latin Square Design with 21 days each period consisting of two weeks adjustment and one week data collection period.

In each period, the goats were randomly allotted to receive basal diets i.e. ad libitum access to urea treated grass hay and 100 g/d *putak* (G), or either supplemented with sun-dried fish (SDF) or fishmeal (FM) (Table 1). *Putak* is the inside starchy part of *gewang* trees (*Coripha gebanga*), i.e. a kind of palm tree. Urea treated grass was made by ensiling the tropical mature grass hay, i.e. dominated by *Botrichloa spp*., with 4% urea at 65% moisture for 28 days. SDF was made by sun-drying while fishmeal (FM) was made by cooking, pressing and drying before grinding. SDF and FM were set iso-nitrogenous at CP level.

The rations were offered twice a day at equal amount at 08^{00} and 16^{00}. The supplement was mixed with *putak* and offered first before the hay.

Parameters and Calculations

Dry matter intake was estimated as the difference between dry matter feed on offer and their residues. The hay residue was collected daily before morning feeding during the third week and sub-sampled for dry matter determination. The supplement and *putak* were completely and quickly consumed. At the same time, feed samples were collected at weighing throughout the experiment and pooled for chemical determination. Dry matter determination on feeds samples was also done at weighing.

The apparent digestibility of dry matter and nutrients were estimated as feed-faeces difference. Faeces were totally collected by putting a plastic layer below the cages. The daily collected faeces was weighed and sampled for about 25% and stored frozen. Dry matter content was determined daily. At the end of each period, faecal samples were thawed, pooled, mixed and dried at low temperature (40^oC) for 48 hours. During the last five days of the collection period, daily urine was also collected in a glass bottles with 20 millilitres of 17% H_2SO_4 and then frozen. They were pooled by treatments and goats afterward and refrozen to wait nitrogen determination.

Rumen fluid samples were collected every two hours for 24 hours in the last day of each collection period. The collected fluids were directly measured for pH and about 40 ml samples were acidified and stored frozen before analyses for ammonia and VFA. Ammonia and VFA were determined on the pooled rumen samples.

In sacco nylon bag technique was used in this study to estimate ruminal degradation of dry matter and protein of hay and fishmeal. Hay was incubated in the rumen of all animals, whereas sun-dried fish and fishmeal were incubated in animals receiving sun-dried and fishmeal supplements. Feeds were ground to pass a 1.5 mm screen and about 1 g of the sample was then weighted into a 7.5 x 10 cm bag made of nylon cloth with a pore size of 37 x 37 μm^2. The bags were thereafter incubated in the rumen for 0, 8, 24, and 96 hours. At time of removal, the bags were then directly frozen. After all bags have been removed from the rumen, they were thawed and washed under running tap water for 1 hour. The residues were transferred from the bag into a nitrogen-free filter paper and dried at 105°C for 20 hours. The degradation data were then fitted to the exponential equation using a simultaneous model as described by Dhanoa (1988), $Y(t) = a$ (for $t \leq t_0$); $Y(t) = a + b(1-e^{-c(t-t0)})$ (for $t > t_0$). Where Y(t) is the degraded part at time t; a is

Table 1. The composition of experimental diets offered to goats

Ingredient	G	SDF	FM
Ammoniated grass hay (grams DM/d)	ad libitum	ad libitum	ad libitum
Putak (grams DM/d)	101	101	101
Sun-dried fishmeal (grams DM/d)	-	18.4	-
Fishmeal (grams DM/d)	-	-	19.7

G : urea-treated grass hay and *putak* as basal diet; SDF : basal diet supplemented with sun-dried fish; FM : basal diet supplemented with fishmeal; DM : dry matter

Table 2. Chemicals composition of feeds used in the diet

Chemical composition	Ammoniated grass hay	*Putak*	Sun-dried fish	Fishmeal
Crude protein (%)	7.24	1.71	64.3	63.9
Crude fibre (%)	32.5	38.2	0.22	0.15
Ash (%)	7.37	4.36	16.0	16.1
Organic matter (%)	92.6	95.6	84.0	83.9
Neutral detergent fibre (%)	66.7	44.8	0	0

the water soluble fraction; b is the insoluble but potentially degradable fraction; c is the degradation rate constant (in h^{-1}); t is the incubation time (in h); t_0 is the lag time (in h).

Whereas, the effective degradability (ED) was calculated as ED = a + ((bc/(c+k)) $*$ e^{-kt0}), where a, b and c values are from the previous model and k is the fractional rate of passage.

Chemical Analyses

Feeds samples were analysed according to the Weende analyses (AOAC, 1990). In addition they were also analysed for NDF following the method of Van Soest et al. (1991) excluding the use of alpha amylase. Ammonia and VFA analyses were done on pooled samples based on times relative to feeding. Ammonia concentration was determined by steam distillation technique, while high pressure liquid chromatography (HPLC) was applied to estimate individual VFA concentration and the sum of those VFAs was assigned as total VFA concentration.

Statistical Analyses

Different parameters were analysed statistically using Proc. GLM (SAS Institute, 2000) suited to Latin Square Design.

Results and Discussion

Effect of Urea Treatment on Quality of Mature Tropical Grass Hay

Changes in the chemical contents of tropical mature grass hay before and after urea-treatment is presented in Table 3. It was obvious from this study that urea treatment markedly improved the quality of mature grass hay. CP content was doubled from 3.5% to 7.24%. This level of CP content was slightly higher than CP content of medium quality grass hay cut at around flowering which contained 6.47% CP as reported by Jelantik (Jelantik and Belli, 2010). NDF content, on the other hand was markedly reduced. As these two feed chemical constituents are known as forage quality indices (Van Soest, 1994), their changes would perfectly explain for the nearly 10% increase in the rumen dry matter degradability of urea-treatment found in this experiment.

Results of the present experiment confirmed many results which convincingly showed that urea as well as ammonia treatment was the obvious strategy to improve the quality, intake and utilisation of low quality roughage by ruminant animals (Vadiveloo, 2000; Brodiscou et al., 2003). The extent of degradation of urea-treated grass hay found in this experiment, however, was still considered to be insufficient to support moderate level of ruminant production as it was also reported by Mgheni et al. (1993) and Swandyastuti and Bata (2010). It is generally recommended that for higher production level an ‘extra supplementation’ be required (Suwandyastuti and Bata, 2010). For the purpose to suffice the nutrition demand for modest growth rate of Kacang goats, sun-dried fish (SDF) and fishmeal (FM) were added together with *putak* (palm pitch), a moderately starch-rich locally available feed, to the ration.

Effect of Sun-dried Fish or Fishmeal Supplementation on Intake and Digestibility of Urea Treated Tropical Grass Hay by Kacang Goats

As presented in Table 4, supplementation of both sun dried fish and fishmeal significantly (P<0.01) increased dry matter as well as nutrient intakes. The result confirms previous findings where fishmeal and fish by-product were supplemented to ruminant fed untreated mature grass hay (Jelantik et al., 2008; Jelantik et al., 2010a). It was also shown that even when the quality of tropical grass mature hay has been improved through urea-treatment and inclusion of a source of energy (*putak*) in the basal diet, improvement could still be obtained through protein supplementation. This result also confirms previous finding where improvement is possible in medium quality grass hay when the supplement was in the form true protein rather than urea (Jelantik and Belli, 2010).

The increase of total dry matter intake in this experiment was apparently due to the 15-20% increase of the intake of ammoniated grass hay in goats supplemented with SDF or FM. This strongly indicated that there was a marked associative effect of sundried fish and fishmeal supplementation on the utilisation of ammoniated grass hay. Results from the digestibility study, however, found the increase of digestibility of ammoniated grass as indicated by NDF digestibility, is small and insignificant (see Table 4). This finding is apparently in contrary to previous reports where the increase of intake of urea-ammoniated was as a result of significant improvement in digestibility (Djajanegara and Doyle, 1990). It should be expected FM and especially SDF supplementation would provide some extra rumen degradable protein which was required by rumen microbes for growth (Bach et al., 2005). An improved rumen fermentation consequently facilitated rumen emptying and therefore increased intake (Poppi et al., 2000).

The failure of protein supplementation to improve digestibility has risen speculation that urea-treatment and addition of a small amount energy-rich feed were sufficient to create an optimal rumen environment favourable for optimal fibre degradation as it will be discussed later. It would be therefore understood that extra RDP would not be able to further improve degradation. Perhaps, this is also the reason for the lack of differences between SDF and FM in affecting digestibility and also intake.

Despite the remarkable difference in rumen CP degradation, it is apparent that DM and especially NDF digestibility were not different between SDF and FM. It would be hypothesized that SDF provided higher RDP to the rumen hereby would improve better rumen environment which stimulate higher degradation rate, faster clearance rate and finally higher intake compared to FM. This was shown in an experiment by Bandyk et al. (2001) and Wickersham et al. (2004) where rumen fermentation were higher when rumen degradable protein was directly infused into the rumen as compared to post-ruminal infusion.

Although we may accept the concept that further improvement in digestibility is not possible when rumen environment has been optimised in G, it is still interesting to discuss factors beyond digestibility that contribute the increased intake in SDF and FM found in this experiment. In a situation when intake is controlled by the rate of rumen emptying, i.e. fill factor, the dominant factor affecting intake other than digestibility is passage rate (Poppi et al., 2001; Schlecht et al., 2007). When intake was improved in the supplemented groups, it is possible that passage rate was increased with FM and SDF supplementation. Although passage rate of ruminal digesta was not measured in this experiment, there was a slight indication that an increase in passage rate with supplementation as shown for example from the faecal data as later showed in Table 7.

Even in a situation where both digestibility and passage rate were not increased by protein supplementation, improved intake could still be observed in ruminant animals supplemented with true protein as shown in our previous experiment (Jelantik et al., 2010a). In the experiment, the intake of low quality grass hay was correlated to rumen fill rather than rumen fermentation and/or passage. Similar effect was reproted by Dixon et al., (2003) who reported the increased intake as a response to oilseed meal supplementation was due to increasing rumen digesta load rather than increased passage and or digestibility. Bandyk et al. (2001) explained that this phenomenom was mediated through improvement of nitrogen status of the animals as well as faster VFA removal from the blood due to higher provision of glucogenic substances such as amino acids (Wickersham et al., 2004). If this is the case in

Table 3. Differences in chemical compositions and rumen dry matter degradation between untreated and urea-treated grass hay

Chemical composition	Untreated grass hay	Urea-treated grass hay
Crude protein (%)	3.53	7.24
Organic matter (%)	92.2	92.6
Neutral detergent fibre (%)	72.6	66.7
Dry matter effective degradation (%)*	30.1	39.6

* assuming passage rate of 2%/h

Table 4. Dry matter and nutrient intake and digestibility

Item	Treatment			SEM	Probability
	G	SDF	FM		
Intake :					
Grass (g DM/d)	200[a]	242[b]	231[b]	11.5	0.05
Total (g DM/d)	305[a]	362[b]	357[b]	9.33	< 0.01
Organic matter (g/d)	282[a]	342[b]	332[b]	10.7	0.01
Crude protein (g/d)	17.3[a]	46.7[b]	46.8[b]	0.90	<0.01
Crude fibre (g/d)	104[a]	120[b]	117[b]	3.74	0.04
NDF (g/d)	179	208	200	7.68	0.08
ADF (g/d)	125	146	140	5.62	0.08
Digestibility :					
Dry matter	58.0	64.3	63.3	3.55	0.5
Organic matter	59.7	66.5	65.2	3.84	0.4
Crude protein	43.2	82.0	80.5	4.00	<0.01
Crude fibre	48.3	52.8	50.7	2.74	0.5
NDF	52.8	54.9	53.9	4.99	0.3
ADF	50.3	53.0	51.3	6.80	0.4

G : urea-treated grass hay and *putak* as basal diet; SDF : basal diet supplemented with sun-dried fish; FM : basal diet supplemented with fishmeal; NDF : neutral detergent fibre; ADF : acid detergent fibre; SEM : standard error of means
Values bearing different superscripts at the same rows differ significantly (P<0.05)

the present experiment, it could be concluded that FM and SDF was comparable in their capacity to improve nitrogen status and providing amino acids to the animals despite their different rumen protein degradability. Similar conclusion was also drawn from the experiment of Wickersham et al. (2004) who found similar capacity of rumen degradable and undegradable protein in improving nitrogen status of ruminant animals. It is therefore clearly showed that in attempt to improve intake of urea-treated mature tropical grass by Kacang goats, there is no further advantage to prepare fishmeal more than sun-drying.

Rumen Environments and Degradation

Data on rumen degradation as well as concentration of some end products of fermentation could be utilised to explain the failure of protein supplementation to improve digestibility. As shown in Table 5, the result of degradation study showed that rumen degradation of ammoniated grass hay was not affected by supplementation of both SDF and FM. The water solubility (a), the insoluble but potentially degradable fraction (b) and consequently effective dry matter degradability at 1 and 2% passage rate were generally comparable among treatments. Since rumen fermentation in fibre-rich fed ruminant accounted for 90% of the total tract digestibility (Huhtanen et al., 2007), this could perfectly explain for the similar digestibility of DM and NDF digestibility across treatment. That the potential degradation has been achieved in G could be shown in small difference between the potential degradation (b value) as compared to the value of the effective degradation at 1% passage rate (ED_1). In this experiment, the effective degradability (ED_1) as a measure of the true degradability at certain passage rate was about 93-98% of the potential degradability of urea ammoniated grass hay. It therefore strongly indicated that rumen degradation has been optimal in G and supplementation of both SDF and FM therefore difficult to improve such degradation.

The absence of the difference in digestibility between unsplemented and supplemented goat nor between SDF and FM was also well confirmed by rumen degradation data as well as some parameters of the rumen environment (Table 6). Rumen pH, ammonia and VFA concentration were not improved by supplementation nor differences between SDF and FM. Rumen pH varied narrowly within the normal level from 6.2 to 6.8 and there was no treatment difference (P>0.05) found in this experiment. Rumen concentration of total VFA was highest for G and followed respectively by FMp and FMd. This trend was also observed for individual VFA. However, they did not differ significantly. When VFA was expressed as molar proportion, supplemented animals had significantly higher (P<0.05) acetate proportion compared to unsupplemented goats. The proportion of propionate did not vary significantly with treatments. A slightly lower but insignificant butyrate proportion was observed in FM as compared to SDF (Table 6).

Data on rumen ammonia concentration revealed that the ruminal ammonia availability was sufficient for microbial growth and activities. Ammonia concentration in all treatment including the basal diet (G) were well above 50 mg/l which is considered the threshold level of rumen ammonia concentration below which rumen microbial production is impeded (Satter and Slyter, 1974). This finding therefore supports the earlier hypothesis that rumen has been in fact optimal in G and supplementation with both SDF and FM was unable to further increase rumen degradation. It is in contrary however with the result of our previous work when intake and digestibility is still obtained when ammonia level above 100 mg/l (Jelantik, 2001).

Protein Balance

Despite large difference in CP intake, the magnitude of CP loss through faeces and urine was apparently unaffected by treatments. But when the faecal loss was expressed as the proportion of CP intake, there was highly significant difference (P<0.01) between the unsupplemented and supplemented goats. Of the CP intake, 56% was recovered in faeces in G compared to only 18-19% in the supplemented animals. This indicate that CP in ammoniated grass hay was less digestible compared to SDF and FM. It was reported that the digestibility of all type of FM was between 89-90% (Silva et al., 1989; Strundsholm et al., 1995). The proportion

Table 5. DM rumen degradation of urea ammoniated grass hay

Item	Treatment			SEM	P
	G	SDF	FM		
a	9.48	9.23	9.28	0.13	0.5
b	47.3	49.9	47.4	1.97	0.7
c	0.054	0.057	0.059	0.012	0.6
Lag time	3.47	4.00	8.47	3.50	0.6
Fill	1.26	1.27	1.27	0.04	0.96
ED_1	46.3	46.9	46.2	1.84	0.95
ED_2	39.6	39.1	38.9	1.70	0.96

G : urea-treated grass hay and *putak* as basal diet; SDF : basal diet supplemented with sun-dried fish; FM : basal diet supplemented with fishmeal ; ED1 is effective degradation assuming passage rate of 1% per hour; ED2 is effective degradation assuming passage rate of 2% per hour; SEM : standard error of means; P : probability

Table 6. PH, ammonia and volatile fatty acids (VFA) concentration of rumen fluid

Parameter	Treatment			SEM	P
	G	SDF	FM		
pH	6.62	6.70	6.81	0.053	0.3
NH_3 (mg/L)	64.1	116	93.3	12.0	0.2
Total VFA (mM)	61.1	44.1	52.1	4.89	0.6
Acetate (mM)	44.6	32.8	40.2	3.65	0.8
Propionate (mM)	12.2	7.67	9.94	0.73	0.3
Butyrate (mM)	4.35	3.69	1.89	0.51	0.3
Acetate (%)	73.0[a]	74.8[b]	75.6[c]	0.20	0.05
Propionate (%)	19.9	17.6	19.1	0.64	0.3
Butyrate (%)	7.10	7.58	3.33	0.74	0.3

G : urea-treated grass hay and *putak* as basal diet; SDF : basal diet supplemented with sun-dried fish; FM : basal diet supplemented with fishmeal. Values bearing different superscripts at the same rows differ significantly (P<0.05)

Table 7. Nitrogen usage by Kacang goats

Parameter	Treatment			SEM	P
	G	SDF	FM		
CP intake (g/d)	17.3a	46.7b	46.8b	0.90	<0.01
DCP intake (g/d)	8.31a	38.2b	37.7b	0.70	<0.01
Faecal CP (g/d)	9.04	8.44	9.08	0.60	0.7
Faecal CP (% of intake)	56.8a	18.0b	19.5b	4.00	<0.01
Urinary CP (g/d)	2.56	6.43	4.71	1.17	0.1
Urinary CP (% of intake)	13.1	13.3	10.2	2.49	0.6
Protein balance (g/d)	5.74[a]	31.8[b]	33.0[b]	1.59	<0.01

G : urea-treated grass hay and *putak* as basal diet; SDF : basal diet supplemented with sun-dried fish; FM : basal diet supplemented with fishmeal; CP : crude protein; DCP : digestible crude protein; P : probability.
Values bearing different superscripts at the same rows differ significantly (P<0.05)

of urinary nitrogen loss as a percentage of intake was comparable among treatments. These resulted in significantly higher protein balance in the supplemented compared to the control goats. The increasing digestible crude protein intake (DCP) in the supplemented goat as compared to the unsupplemented counterpart apparently explained most of the difference as protein balance in the present experiment was best related to DCP.

Notable difference between SDF and FM in the efficiency of the digestible protein utilised for meat production was absent in the present experiment. Similar results was also reported by Silva et al., 1989; Strundsholm et al., 1995) where similar growth performance was shown in lambs maintained on diets differing in rumen protein degradability. As protein balance is predominantly determined by the extent and quality of absorbed amino-acids in the intestine, i.e. the non ammonia nitrogen flow (NAN-flow) out of the rumen (Van Soest, 1994), the capacity of both SDF and FM was therefore comparable in the present experiment. Improved microbial protein synthesis in SDF might have upset the higher amount protein escape in FM. Thus, it is apparent from this experiment that there is no obvious advantage of processing raw fish to become fishmeal but sun-drying

Conclusions

The intake of urea-treated low quality grass hay and particularly total dry matter as well as nutrients intake were increased by supplementation both SDF and FM at a comparable level. Supplementation of both SDF and FM failed to improve rumen degradation, rumen environment and consequently total tract digestibility of dry matter and other nutrients but protein. The intake, digestibility and nitrogen balance were markedly improved with supplementation of both SDF and FM. Since protein balance was improved regardless the source of supplemented protein, it could be concluded that there is no further advantage of processing fish rather than sun-dried.

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