The Nutritive Value of Mulberry Leaves (*Morus alba*) and Partial Replacement of Cotton Seed in Rations on the Performance of Growing Vietnamese Cattle

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ABSTRACT : The *in vivo* digestibility of mulberry leaves (*Morus alba*) and the effects of the partial replacement of cotton seed with fresh mulberry leaf in rations on the performance of growing Vietnamese cattle was investigated. For the *in vivo* digestibility trial, twenty castrated rams of Phanrang breed (a local prolific breed) with an initial weight of 23-25 kg, were first assigned to four groups according to weight and then randomly assigned to one of four dietary treatments to determine digestibility of nutrients in mulberry leaves (*M. alba*), natural Bermuda grass (*Cynodon dactylon*), elephant grass (*Pennisetum purpureum*) and buffalo grass (*Panicum maximum* cv. TD 58). All forages were cut and chopped daily before being offered (at 120% maintenance) to the sheep. In the feeding trial, 20 Laisind (Vietnam yellow cows×Red Sindhy bulls) crossbred bulls averaged 18 month old and 184 kg were used to investigate the effect of partial replacement of cottonseed in the diet by mulberry leaves on live weight gain and feed conversion rate. The experiment was a randomized complete block design with four levels of fresh mulberry leaves which varied from 0 to 15% of total dietary dry mater and five animals per treatment over an 84 day period. The *in vivo* digestion trial showed the superior quality of mulberry leaves compared with the grasses. Chemical analysis indicated that mulberry leaves had the highest CP and the lowest NDF contents (22.3 and 31.1% DM, respectively) among the four forages tested. Digestibility of DM and OM of the mulberry leaf (66.4 and 71.8%, respectively) was also the highest but that of CP (58.2%) and NDF (58.4%) was the lowest of the four forages evaluated (p<0.05). Consequently, the ME value and therefore net energy (NE) and unit feed for lactation (UFL) values of the mulberry leaves, which was estimated from chemical composition and digestibility values, were the highest among the forages investigated in the present study. Results of the feeding trial showed no treatment effect on average daily gain (ADG) of the cattle. The values were 554, 583, 565 and 568 g/d for animals in the diets of 0, 5, 10, and 15% mulberry leaves inclusion, respectively. Total DM intake of the animal was not affected by the treatment when expressed as kg/animal/d. However, when adjusted for metabolic weight of the animal the DM intake was reduced (p<0.05) as whole cottonseed was replaced by mulberry leaves in the ration. When the level of mulberry leaves in the ration increased from 5 to 15% of dietary DM at the expense of whole cottonseed, CP and ME intakes of the cattle were significantly decreased (p<0.05) and the feed to gain ratio reduced by 8 to 14% as compared with the control diet (p<0.05). Mulberry leaf is a good feed ingredient for ruminants because of its high level of crude protein and high digestibility of nutrients and energy. Mulberry leaves can be efficiently used as a source of protein supplement to replace cottonseed, a more expensive animal feeds ingredient, in the diet for Vietnamese cattle. (**Key Words :** Mulberry Leaves, Digestibility, Nutritive Value, Cattle, Growth Performance)

INTRODUCTION

The fibrous residues from cereal crops, agro-industrial by-products, cut and carry weeds/grasses, foliage of trees, shrubs and water plants (Leng, 2002; Khampa and Wanapat, 2007) are major components of the basal diet of ruminants in the tropics. These diets often have low protein and organic matter digestibility, low energy content and unbalanced essential minerals (Ash, 1990; Garg and Gupta, 1992). Thus feeding these diets to ruminants often results in low voluntary intakes and hence low growth rates (Shayo, 1997). There are several alternatives for improving the performance of ruminants fed these low quality basal diets. One of the alternatives is to use trees and shrubs which are high in protein content but have moderate to high digestibility (Egan, 1997).

Recently, in many tropical countries and regions, there

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has been a focus on indentifying and using locally available shrubs and tree leaves as a source of feeds or feed ingredients for ruminants because of their high nutritive value and positive effects on rumen function (Ormar et al., 1999; Yao et al., 2000). Mulberry trees, which belong to the *Urticales* order, *Moraceae* family and *Morus* genus, have been used traditionally as a major feed for silkworms in Vietnam and over the world (Tingzing et al., 1988) for centuries. However, due to its high protein content (Nguyen Xuan Ba et al., 2005) with which quality is comparable or even superior to that of soybean meal (Marchii, 1989) mulberry leaves can also be used alternatively as a high protein feed for the ruminant. Nevertheless, the utilization of this tree as part of ruminant feeds has until now not been practiced in Vietnam. The objectives of the present study were to evaluate the effects of the partial replacement of cotton seed with fresh mulberry leaves in rations on the performance of growing cattle and to determine *in vivo* digestibility and nutritional value of mulberry leaves (*M. alba*). Nutritional values of natural Bermuda grass in the natural pasture (*Cynodon dactylon*), elephant (*Pennisetum purpureum*) and buffalo (*Panicum maximum* cv. TD 58) grasses were also determined under the same digestion trial to provide indication of the superiority of mulberry leaves on conventional forages.

MATERIALS AND METHODS

The *in vivo* digestibility trial

The *in vivo* digestion trial was conducted at the experimental station of the National Institute of Animal Sciences, Thuyphuong, Tuliem, Hanoi, Vietnam to evaluate nutritive value of mulberry leaves and three grasses. The study was designed as a randomized block design with four forages to be evaluated on five animals each. At the beginning of the experiment, twenty castrated rams of Phanrang breed (a local prolific sheep breed) with an initial weight of 23-25 kg were blocked according to their live weight into 4 groups, each with five animals. The groups were then randomly allocated to one of the following treatments:

A: Chopped natural Bermuda grass (*Cynodon dactylon*)
B: Chopped elephant grass (P. *purpureum*)
C: Chopped buffalo grass (P. *maximum* cv.TD 58)
D: Chopped mulberry leaves (*M. alba*)

All forages were freshly cut and chopped by hand just before each feeding. The analyzed composition of the four forages is presented in Table 1.

All sheep were kept in individual metabolism cages and fed their respective diet twice a day at 9 am and 16 pm. The level of feeding was aimed at 120% of their maintenance requirements. All animals were offered free access to clean water and mineral block; yet no supplement was provided.

The apparent digestibility of the grass and mulberry leaves was calculated from the amount of feed offered, its chemical composition corrected for feed residues and from the amount and chemical composition of the feces. Digestibility was measured over a 10 day period following a 20-d acclimatization period. All feed offered to the sheep for the 10-d fecal collection period was weighed and sampled daily. Feed refusals were also weighed, sampled daily and the DM of the refusal was determined. Daily faecal output was measured by total collection into individual trays placed underneath the metabolism crates. The daily faecal collection for each ram was mixed, and a 5% aliquot was taken and kept in a freezer. At the end of the collection period, these samples were thawed, bulked, mixed and a sub-sample was taken for each sheep. Ten day composite samples of feeds, refusals and feces were dried at 55°C to a constant weight for the determination of dry matter (DM). Feed and feces samples were ground (1-mm screen) and analyzed for ash (muffle furnace at 550°C for 4 h), crude protein (CP) (AOAC official method 954.01, AOAC, 1997, Kjeldahl N× 6.25), crude fiber (CF) (AOAC official method 978.10, AOAC, 1997), ether extract (AOAC official method 920.39, AOAC, 1997), ash free neutral detergent fiber (NDF) and acid detergent fiber (ADF) (Van Soest et al., 1991). Energy and metabolizable protein values of mulberry leaves and the grasses were calculated from the *in vivo* digestibility data, using the equations developed by Jarrige (1989). Energy values were calculated from

Table 1. Analyzed composition of mulberry leaves and three grasses from the *in vivo* digestibility trial

Component	Bermuda grass (*C. dactylon*)	Elephant grass (*P. Purpureum*)	Buffalo grass (*P. max.* cv.TD 58)	Mulberry leaves (*M. alba*)
Dry matter	22.6	13.3	21.0	19. 8
Organic matter	84.0	85.5	89.2	86.4
Crude protein	11.6	10.3	11.5	22.3
Ether extract	2.1	2.1	2.4	3.5
Crude fiber	27.4	34.0	35.8	15.9
NDF	67.1	63.1	67.8	31.1
ADF	31.6	36.2	38.8	18.3

Values are expressed on a dry matter basis (%). NDF = Neutral detergent fiber; ADF = Acid detergent fiber.

equations 2.1, 2.2, 2.3, 2.8, 13.3, 13.7, and 13.13 and metabolizable protein from equation 3.1 and those in Table 3.1 with deg and dsi values in Table 13.3 in the book edited by Jarrige (1989). Reasons for using these equations were that the French feed evaluation has been used in North Vietnam for 10 years and the available database has been fitted to these equations.

Equations used in nutritive value determination of Experimental feedstuffs according to the French system (Jarrige, 1989).

GE (Kcal/kg OM)
$$= 4543 + 2.0113 \, CP \, (g/kg \, OM)$$
(for green or dried roughage and silage) (1)

GE (Kcal/kg DM)
$$= 5.72 \, CP \, (g/kg \, DM) + 9.50 \, EE \, (g/kg \, DM)$$
$$+ 4.79 \, CF \, (g/kg \, DM) + 4.17 \, NFE \, (g/kg \, DM) + \Delta$$
(for by-products) (2)

DE (Mcal/kg DM)
$$= GE \, (Mcal/kg \, DM) \times dE \,/100;$$
and $dE \, (\%) = (1.0087 - OMD) - 0.37$ (3)

ME (Kcal/kg DM)
$$= DE \times (ME/DE);$$
and $ME/DE = 0.8417 - [9.9 \times 10^{-5} EE \, (g/kg \, OM)]$
$$- [1.96 \times 10^{-4} CP \, (g/kg \, OM)] + 0.221 \times L$$
(L = 1 at maintenance) (4)

NE (Kcal/kg DM) = ME×k;
kl = 0.60+0.24 (q-0.57); km = 0.287 q+0.554;
q = ME/GE (5)

UFL = ME×kl/1,700 (6)

PDI = PDIA+PDIM;
PDIN = PDIA+PDIMN;
PDIE = PDIA+PDIME (7)

PDIA (g/kg DM)
$$= CP \, (g/kg \, DM) \times 1.11 \, (1\text{-deg}) \times dsi$$ (8)

PDIMN (g/kg DM)
$$= 0.64 \times CP \, (g/kg \, DM) \times (\text{deg} - 0.10)$$ (9)

PDIME (g/kg DM)
$$= 0.093 \times [OMD - (CP \, (g/kg \, DM)$$
$$\times (1\text{-deg}) - EE \, (g/kg \, DM))]$$ (10)

The feeding trial

A 84 day feeding trial was undertaken at Tamxa village, Donganh district, Hanoi, in the Red River delta of Vietnam. In this experiment, 20 Laisind (Vietnam yellow cows×Red Sindhy bulls) crossbred young bulls of 18 months of age and 184 kg on average were used. Animals were kept in individual pens (2.8×1.1×2.0 m in dimensions) constructed from brick walls and thatched roofs which were naturally ventilated.

The trial was a completely randomized block design with four dietary treatments and five animals per treatment. At the beginning of the experiment, the young bulls were blocked according to their live weight into 5 blocks, each with four animals. Within a block, the animals were each randomly allocated to one of the four dietary treatments. Cattle were treated with Fasinex (Ciba Co., Basel, Switzerland) for the control of internal parasites and were fed the experimental diets for a preliminary period of 15 days before starting the experiment. Animals were offered free access to clean water and fed *ad libitum* twice a day at 8 am and 16 pm (feed residue equated to 15-20% of the total feed offered on the previous day).

Experimental diets were prepared from the basal diet which contained 40% molasses, 23% whole cotton seed, 20% chopped rice straw, 10% of cassava meal, 5% soy bean meal 1% urea and 1% mineral premix (DM basis). Different amounts of whole cottonseed in the basal diet were replaced by mulberry leaves to such levels that the mulberry leaves eventually constituted 0, 5, 10, and 15% of the dietary DM. Mulberry leaves were picked freshly every day and chopped by hand to approximately 1×2 cm in dimensions. Rice straw was also chopped by hand to 2-3 cm in length. Cassava meal, ground whole cotton seed, soy bean meal and the mineral premix were mixed thoroughly and then mixed with chopped fresh mulberry leaves and rice straw. Finally, this was mixed with the urea and diluted molasses. The mineral premix contained the following vitamins: A (4,000,000 IU/kg), D_3 (1,000,000 IU/kg), E (8,200 mg/kg), K_3 (8,200 mg/kg), B_1 (8,200 mg/kg), B_2 (8,200 mg/kg), B_6 (8,200 mg/kg), B_{12} (120 mg/kg), niacin (3,000 mg/kg), pantothenic acid (5,000 mg/kg), folic acid (60 mg/kg), biotin (60 mg/kg) and minerals: Zn (16,000 mg/kg), Fe (10,000 mg/kg), Cu (2,000 mg/kg), Mn (16,000 mg/kg), Co (200 mg/kg), I (120 mg/kg), Sc (60 mg/kg). The chemical composition of the ingredients is shown in Table 2.

Feeds offered and refused were recorded daily for each animal with the latter determined each morning before feeding. Live weights were obtained at 14 day intervals throughout the trial, immediately prior to feeding at 8 am. Total DM intake (DMI) was estimated directly by the difference between the weight of feed offered and the refusal for each animal. Representative samples of the feeds and refusals were taken every 14 days for chemical analysis. Actual CP and ME intakes were calculated from values of DMI for the 84 days for each animal and CP and ME

Table 2. Analyzed composition of the feed ingredients used in the feeding trial

Feed	DM	CP	NDF	ADF	Total ash
Cassava meal	85.4	4.34	19.4	4.1	2.96
Molasses	76.7	1.82	-	-	6.24
Whole cotton seed	89.4	21.0	55.0	34.1	4.32
Soybean meal	91.1	36.7	14.2	10.8	5.60
Mulberry leaves	20.8	20.3	32.4	18.7	14.5
Chopped rice straw	85.1	5.08	73.2	42.6	15.1

All values are expressed as percentage of dry matter except for the dry matter itself.
DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber.

contents of the feed ingredients. Feed conversion ratio (FCR) was calculated from total DMI and the value of ADG for the 84 day feeding period for each animal.

Statistical analysis

The data from the *in vivo* study and the feeding trial were subjected to analyses of variance (ANOVA) for a completely randomized block design using the GLM procedure of the SAS system for Windows (SAS 6.12, TS level 020, SAS institute). The following model was used for analysis of data:

$$Y_{ijk} = \mu + tx_i + bl_J + e_{ijk}$$

Where μ is the overall mean, tx_i is the ith treatment effect, bl_J is the jth block effect and e_{ijk} is the experimental error of treatment i in block b. For the treatments which showed differences, the means were compared using Turkey's procedure at $p < 0.05$.

RESULTS

The *in vivo* digestion trial

The chemical composition of mulberry leaves and the three grasses, expressed on a dry matter basis, is presented in Table 1. Among the four forages studied, CP content of the mulberry leaf was the highest (22.3%) while that of *P. purpureum* was the lowest (10.3%) with the content of *C. dactylon* and *P. maximum* cv. TD 58 intermediate. The CF,

NDF and ADF content of the mulberry leaf were the lowest (15.6, 31.1 and 18.3%) while those of *P. maximum* cv. TD 58 the highest (38.5, 67.8 and 38.8%) with the intermediate values for *C. dactylon* and *P. purpureum*. Ether extract (EE) content in mulberry leaves (3.5%) was the highest, followed by *P. maximum.* cv.TD 58 (2.4%) and *C. dactylon*, *P. purpureum* (2.1%). Ash content in *C. dactylon* was the highest (16.0%), followed by *P. purpureum* (14.5%) and mulberry leaves (13.6%); that of *P. maximum* cv. TD 58 was low (10.8%).

Table 3 presents the *in vivo* digestibility of nutrients in the mulberry leaf and three grasses. It can be seen from the table that DM and OM digestibilities of mulberry leaves (66.4 and 71.8%) were the highest ($p < 0.05$) and that of *C. dactylon* the lowest (52.7 and 58.8%, respectively). Digestibility of DM and OM of *P. purpureum* (62.9 and 66.2%) were higher than that of *P. maximum* cv. TD 58 (60.2 and 62.9%, respectively). However, CP digestibility of the mulberry leaf was lower ($p < 0.05$) than the value of *P. maximum* cv. TD 58, yet it was similar to that of *C. dactylon* and *P. purpureum*. Similarly, the digestibility of NDF and ADF of the mulberry leaf (58.4 and 52.8%) were lower ($p < 0.05$) as compared to that of *P. purpureum* (66.8 and 67.3%) and *P. maximum* cv. TD 58 (62.8 and 63.5%), but similar to that of *C. dactylon* (60.7 and 54.6%). The digestibility of EE in mulberry leaves (49.4%) was lower ($p < 0.05$) than that of *C. dactylon* (53.3%), but higher than the values of *P. maximum* cv. TD 58 (44.9%) and of *P. Purpureum* (43.8%).

Table 3. Apparent digestibilities of mulberry leaves and three grasses

Component	Bermuda grass (*C. dactylon*)	Elephant grass (*P. Purpureum*)	Buffalo grass (*P. max.* cv. TD 58)	Mulberry leaves (*M. alba*)	Pooled SEM
Dry matter	52.7[a]	62.9[b]	60.2[c]	66.4[d]	5.43
Organic matter	58.8[a]	66.2[b]	62.9[c]	71.8[d]	5.27
Crude protein	58.9[a]	60.8[a]	67.8[b]	58.2[a]	6.21
Ether extract	53.3[a]	43.8[b]	44.9[b]	49.4[c]	5.15
Crude fiber	56.3[a]	69.5[b]	65.1[c]	50.8[d]	7.52
NDF	60.7[a]	66.8[b]	62.8[c]	58.4[a]	3.79
ADF	54.6[a]	67.3[b]	63.5[c]	52.9[a]	5.45

DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber.
Values with different superscripts within a row are significantly ($p < 0.05$) different.

Table 4. Calculated[1] energy and protein values of the mulberry leaf and three grasses for growing Laisind cattle in Vietnam

Component	Bermuda grass (*C. dactylon*)	Elephant grass (*P. Purpureum*)	Buffalo grass (*P. max.* cv. TD 58)	Mulberry leaves (*M. alba*)	Pooled SEM
Energy (MJ/kg DM)					
ME	7.97[a]	8.63[b]	8.70[b]	10.11[c]	0.41
NE	4.60[a]	5.06[b]	5.04[b]	6.02[c]	0.24
UFL	0.64[a]	0.70[b]	0.70[b]	0.83[c]	0.09
Protein (g/kg DM)					
PDI	83[a]	74[b]	82[a]	138[c]	0.08
PDIN	87[a]	74[b]	82[a]	160[c]	0.89
PDIE	83[a]	85[a]	90[b]	138[c]	0.76

ME = Metabolisable energy; NE = Net energy; UFL = Unit feed for lactation; PDI = Intestinally digestible proteins;
PDIN = PDI when nitrogen in feed is limiting; PDIE, when energy in feed is limiting.
Values with different superscripts within a row are significantly (p<0.05) different.
[1] Calculated from the data in the present study and equations of Jarrige (1989).

The calculated energy and protein values of the mulberry leaf and three grasses are presented in Table 4. In comparison to the grasses, the ME value (10.11 MJ/kg DM) and therefore calculated NE (6.02 MJ/kg DM) and the UFL (0.83) values of the mulberry leaves were the highest (p<0.01), followed by that values of *P. purpureum* and *P. maximum* cv. TD 58, and *C. dactylon*. Similarly, the value for digestible protein in the small intestine (PDI) of mulberry leaves was the highest (p<0.01), followed by *C. dactylon*, *P.maximum* cv. TD 58 and *P. purpureum*.

The feeding trial

Growth rate, feed intake and feed utilization of the cattle are shown in Table 5. There was no treatment effect on growth rate of the cattle although the ADG values of the cattle fed mulberry leaves were numerically higher than that of the control diet (no mulberry inclusion). Over the entire experimental period, ADG for the control diet and three mulberry leaves included diets were 554, 583, 565 and 568 g, respectively. The total DMI in the present study ranged

from 4.64 to 5.19 kg/d and was similar among all groups of cattle. However, the DMI (g DM/kg BW$^{0.75}$), the CP and ME intake of cattle were affected (p<0.05) by treatment. When the level of mulberry leaf inclusion in the diet increased, the CP and ME intakes of cattle were decreased (p<0.05). Among the four treatments, the FCR of the animals fed the control diet was the highest and that of animals fed the 5% mulberry leaves diet the lowest with values of animals fed 10% and 15% mulberry leaf diets intermediate (p<0.05).

DISCUSSION

The chemical composition of mulberry leaves

The chemical composition of mulberry leaves in our study was in the same range as data reported elsewhere (Benavides et al., 1986; Deshmukh et al., 1993; Shayo, 1997; Singh and Makkar, 2002; Phiny et al., 2003; Bamikole et al., 2005; Kabi and Bareeba, 2008; González-García et al., 2008). Though some values of less than 16%

Table 5. Effect of different additions of mulberry leaves on live weight gain and feed intake of growing Laisind cattle during the 84 day trial

Parameter	Dietary mulberry leaf content (%)				Pooled SEM
	0	5	10	15	
Initial weight (kg)	183.8	184.8	183.8	183.5	9.12
Finishing live weight (kg)	230.3	233.8	231.3	231.3	12.12
Live weight gain (kg)	46.5	49.0	47.5	47.8	4.89
ADG (g/animal/d)	554	583	565	568	7.49
DM intake (kg DM/animal/d)	5.19	4.64	4.73	4.68	0.31
DM intake as % bodyweight	2.56	2.42	2.35	2.41	0.11
DM intake (g DM/kg BW$^{0.75}$/d)	96.3[a]	91.2[ab]	88.7[b]	89.9[b]	2.26
CP intake (g CP/animal/d)	607.2[a]	541.4[b]	550.4[b]	543.4[b]	28.45
ME intake (MJ ME/animal/d)	48.3[a]	45.5[a]	43.9[b]	41.8[b]	3.47
FCR (kg DM/kg gain)	9.36[a]	7.94[b]	8.37[b]	8.23[b]	0.31

ADG = Average daily gain; BW = Body weight; CP = Crude protein; DM = Dry matter; FCR = Feed conversion ratio; ME = Metabolisable energy.
Values with different superscripts within a row are significantly (p<0.05) different.

were observed (Kantwa et al., 2006; Ngamsaeng et al., 2006), most of the CP values of mulberry leaves reported in the literature was higher than 20% (Benavides et al., 1986; Deshmukh et al., 1993; Singh and Makkar, 2002; Phiny et al., 2003; Bamikole et al., 2005; González-García et al., 2008). Therefore despite the fact that CP content of mulberry leaves varied considerably due probably to maturation stage (Kabi and Bareeba, 2008), climatic conditions (Wilson and Wong, 1982), soil manure application and cutting frequency (Benavides et al., 1994; Espinoza and Benavides, 1996; Kabi and Bareeba, 2008), the value reported in the previous and present studies indicates that mulberry leaves could be a high protein forage for farm animals.

The relatively low fiber and high ash contents of the mulberry leaf in this study were also in agreement with the values reported by other authors. A CF content of 9.1-15.3% DM could be found in the work of Jayal and Kehar (1962), Singh et al. (1984), Makar et al. (1989), Signh et al. (1989), Shayo (1997), and González-García et al. (2008). The NDF content of mulberry leaf observed in different regions in the world was reportedly varied from 26.6 to 46.0% and ADF content from 18.7 to 35% (Makar et al., 1989; Shayo, 1997; Ormar et al., 1999; González-García et al., 2008; Kabi and Bareeba, 2008). The ash content of mulberry leaves in the present study was higher than the value (6.4-13.3%) observed by Bamikole et al. (2005), Ngamsaeng et al. (2006) and Kabi and Bareeba (2008) but similar to or lower than the values reported by other workers (Gohl, 1981; Singh et al., 1984; Deshmukh et al., 1993; Kandylis et al., 2009).

Mulberry leaves and three grasses investigated in the present experiment were all harvested at relatively early stage of maturation in mid spring. Therefore, higher protein and lower fiber contents of mulberry leaves as compared to that of *P. purpureum, P. maximum* cv. TD 58 and *C. dactylon* was expected. Mulberry belongs to the legume family which normally has higher CP and lower fiber contents than the tropical grasses. Similar results were also reported by Mtui et al. (2009) in which *P. purpureum* and *P. maximum*, *C. plectostychus* and mulberry leaves harvested in wet season, a similar climatic condition to that in the present experiment, had CP content of 11.0, 10.9, 12.0, and 22.2%, respectively. The NDF content of mulberry (38.4%) and P. *maximum* (77.5%) in their work were slightly higher but that of the other grasses (65.6-65.9%) similar to the values observed in the present study. The ADF content of mulberry leaves and three grasses in the work of Mtui et al. (2009), however, was higher than the respective values in the present study. Higher CP and lower NDF contents of mulberry leaves as compared with the grasses in the work of Mtui et al. (2009) and the present study clearly indicated that mulberry leaves had higher nutritional quality as feed

for the ruminants than the tropical grasses.

The *in vivo* DM digestibility of mulberry leaves observed in the present study is higher than the value of 61.3% recently reported by Doran et al. (2007) but lower than that of 79.3% reported by Jegou et al. (1994). However, it should be noted that the mulberry forage used in the work of Doran et al. (2007) was dried and contained both leaves and stems whereas the value reported by Jegou et al. (1994) was obtained from a digestion trial on goats. Dry mulberry foliage had CP content of only 16.2% (Doran et al., 2008) which might have caused a reduced DM digestibility while different animal species have been shown to cause variations in digestibility of roughages (Playne, 1978; Kawashima et al., 2007).

The *in vivo* DM digestibility in the present study was comparable to that reported by González-García et al. (2008) on fresh mulberry forage harvested in rainy season. The mulberry in their study had a very similar DM, CP, NDF and ADF contents to that investigated in the present study and its DM digestibility determined on sheep was 69.9. However, the digestibility of OM (79.2%) of the forage in the work of González-García et al. (2008) was higher than the value observed in the present study. The differences in ash content and digestibility between the two mulberry forages might be the major reason for such discrepancy in OM digestibility between the two studies.

The digestibility of CP of mulberry leaves in the present study was relatively low as compared with the value of 69.5-75% reported by other workers (Jayal and Kehar, 1962; Doran et al., 2008; González-García, et al., 2008). Digestibility of NDF and ADF, however, was higher than the value reported by Doran et al. (2007) on dry mulberry foliage. Drying might have changed physical and chemical structure of the fiber in the mulberry and hence reduced the ability of the rumen microbes to attack and digest the fiber.

Higher digestibility of DM and OM and lower fiber content of mulberry leaves as compared with the respective values of the grasses indicated that the lower fiber digestibility of the leaves was probably due to its high CP and non-structural carbohydrate contents which might have resulted in a higher passage rate of the rumen digesta and hence lower fiber digestibility. However, the passage rate was not measured in the present study.

The ME value of mulberry leaves in present study was in the same range as data reported elsewhere. For example, González-García et al. (2008) found an ME value of 10.1-10.2 MJ/kg DM when fresh mulberry leaves with a similar chemical composition to that in the present experiment were examined on sheep. Lower ME values of 9.13 and 9.46 MJ/kg DM were reported for mulberry leaves determined by Kantwa et al. (2006) on sheep and goats respectively whereas a higher value of 10.8 MJ/kg DM was recorded on rabbit (Deshmuskh et al., 1993). In addition, Kabi and

Bareeba (2008) estimated ME value of mulberry leaves at different maturing stages from *in sacco* OM disappearance at 48 hours in the rumen of cattle and reported values in the range of 7.7-12.1 MJ/kg DM.

The PDI value of mulberry leaves observed in the present study was slightly higher than that in the report of González-García et al. (2008) (117-120 g/kg DM). However, in both studies the PDIE was always lower than PDIN, suggesting that mulberry leaves should not be fed as unique feed to the ruminant but in combination with an energy source to maximize the utilization of the protein in the leaf.

Higher ME and subsequently NE values of the mulberry leaf as compared with that of the grasses evaluated in the present study was due to its higher OM digestibility. Similarly, higher CP had resulted in a higher PDI value of the mulberry leaves as compared with the grasses. Thus data of chemical composition, *in vivo* digestibility, ME, NE and DPI values in the present study clearly illustrate that nutritive value of the mulberry leaf was considerably higher than value of conventional grasses and that mulberry leaves should be used as a source of protein supplement in diets for the ruminants.

Growth rates of the cattle

Growth rate of the bulls in the present experiment was in a normal range of live weight gains commonly achieved with this type of cattle and feeding regime in Vietnam. Although many studies have been conducted to determine the response of small ruminants and rabbits to feeding different levels of mulberry leaves, data on growth rate of cattle in the literature are scarce. Thus Gonzalez et al. (1996) fed young Romo-sinuano bulls a basal diet of elephant grass (*P. purpureum*) supplemented with mulberry foliage at levels of 0, 1, 1.9, and 2.8% LW and observed a significant increase in ADG of the supplemented groups. The ADG jumped from 40 g/d in the control group (no mulberry supplement) to 690 g/d in the group supplemented with mulberry at 1% LW. However, increasing the level of mulberry from 1.9 to 2.8% LW did not result in any significant improvement in growth rate with the value varied between 940 and 950 g/d. When ensiled mulberry foliage was supplemented to a basal diet of elephant grass (*P. purpureum*) young Romosinuano bulls achieved much lower growth rates (Vallejo, 1994 as cited by Benavides, 2002). The ADG of animals in groups supplemented mulberry silage at levels of 0, 0.66, 1.7 and 2.5 percent of live weight was only 117, 404, 490 and 601 g/d, respectively. Grazing dairy heifers supplemented with either concentrate, or mulberry foliage, or mixture of mulberry and concentrate (50:50) at a fixed level of 1% live weight in the work of Oviedo and Benavides (1994) showed no differences in growth rate and the maximal ADG of 742 g/d was achieved in the group supplemented with both concentrate and mulberry. Though results from these studies could not be directly compared with that in the present study due to differences in level and nature of the mulberry included in the diet as well as animal genotype and climatic condition, it would be relevant to postulate that a high growth rate of cattle could be achieved with diets containing mulberry forages.

Given higher ME and CP intake of the control diet as compared with the mulberry supplemented diets in the present study, it is difficult to explain why no difference in ADG of the animal was observed. A possible explanation is that ME intake calculated as a sum of ME from the individual ingredients did not reflect the actual value of the whole diet as interaction between ingredients might occur. The work by Doran et al. (2007) demonstrated that combination of mulberry foliage with such low quality roughage as oat hay could produce a positive interaction on protein and NDF digestibility whereas combination between alfalfa and oat hay showed no associative effect on NDF digestibility and negative effect on DE. Thus mulberry leaves might produce positive interactions with other ingredients including cottonseed on carbohydrate and protein digestion and, therefore, actual ME value of the diets supplemented with mulberry leaves might be higher than the value presented in this report. Reversely, cottonseed might have negative interactions with other ingredients in the control diet on digestibility of nutrients and caused a lower ME value than the currently presented one. In addition, though cottonseed *per se* had slightly higher ME value (10.3 MJ/kg DM; Vu et al., unpubl. data) than that of the mulberry leaf, its NE value might be the same or even lower as heat produced from eating and digesting of whole cottonseed might be higher than that of the fresh mulberry leaves. However, both interactions between mulberry and cottonseed with other ingredients in the diet and NE value of whole cottonseed were not determined in the present study.

The use of CP unit is also a shortcoming of the present study. Though animals in the control group consumed more CP than that in the mulberry supplemented groups, the actual amount of protein that are digestible in small intestine of the animal (or DPI value) received by the control group might be similar or even lower than that obtained by animals in the other groups. This postulation is supported by suggestion of Singh and Markar (2002) that high digestibility of OM and high contents of highly fermentable carbohydrates, vitamin, nitrogen, sulfur and other minerals in mulberry leaves could result in high efficiency of microbial protein synthesis in the rumen and hence microbial protein supply to the small intestine of the ruminant animals. Thus total amount of amino acids available for growth and hence ADG of animals in all groups might not be different despite of higher CP intake in

the control group.

Feed intake and feed utilization of cattle

Total DMI in the present study was in a close agreement with the published value which ranged from 4.2 to 5.6 kg DM/animal/d for growing bulls weighing 150-250 kg and gaining 0.5 kg/d (Kearl, 1982). This indicates that the feed was accepted readily by the bulls in the present study and that they had no problem in achieving a DMI similar to the requirements for gain of about 0.5 kg/animal/d. Calculated from the total DMI, intakes of CP and ME of cattle ranged from 541.4 to 607.2 g and from 41.8 to 48.3 MJ/animal/d, respectively. These CP and ME intakes were in a close agreement with CP and ME requirement, which have been reported to be 600 g and 48 MJ for growing bulls weighing 150-250 kg and gaining 0.5 kg/d (Kearl, 1982).

Total DMI, expressed as g/kg $BW^{0.75}$, was decreased as level of mulberry leaves in the diet increased at the expense of cottonseed in the present study. Similar trend was also observed by Benavides et al. (2002) who reported a decrease in total DMI as proportion of mulberry increased at the expense of concentrate in the supplement offered to grazing dairy cattle. As fresh mulberry was bulky (Esquivel et al., 1996) it seems that a physical limitation had played a certain role in intake regulation in the present study. However, this would not be the only mechanism controlling intake of the animal as increasing level of mulberry leaves from 10 to 15% of the dietary DM did not result in any further decrease in total dietary DMI. Since intake of all treatments including the control diet was relatively low, it may be assumed that high osmolarity due to a high level of various minerals (K, Ca, Mg, Cl) in molasses and mulberry leaves in the present study might affect intake of the animals (Ternouth, 1965; Dinh Van Tuyen, 2006).

Due to a numerical decrease in total DM intake as mulberry leaves replaced cottonseed in the rations and the higher ME and CP contents of cottonseed, intakes of CP and ME decreased with increasing level of mulberry in the diet. However, it was interesting that despite of a decrease in CP and ME intakes the ADG of bulls in the mulberry supplemented groups were numerically higher than that of animals in the control diet. As a result animals consuming mulberry diets archived lower feed to gain ratios (FCR) than those in the control group. Higher efficiency of feed utilization of animals in the mulberry supplemented groups may come from a more efficient interaction between mulberry leaves and other feeds in the diet and a possibly higher efficiency of microbial protein synthesis in the rumen and hence DPI value of mulberry leaves as compared with the whole cottonseed.

The present study shows that the mulberry leaf is a good feedstuff for ruminants. High CP content and *in vivo* OM digestibility make it superior to those of most commonly used tropical grasses and nearly comparable to concentrates. When used as a supplement, it can replace cottonseed without any negative effect on ADG but improve feed utilization by growing cattle. The replacement of cottonseed with fresh mulberry leaves at such level that mulberry accounting for 5 to 15% dietary DM in the rations of growing cattle can reduce feed to gain ratio by 8 to 14%.

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