Comparative Study between Swamp Buffalo and Native Cattle in Feed Digestibility and Potential Transfer of Buffalo Rumen Digesta into Cattle

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ABSTRACT : Rumen ecology plays an important role in the fermentation process and in providing end-products for ruminants. These studies were carried out to investigate variations in rumen factors namely pH, NH_3-N and microorganisms in cattle and swamp buffaloes. Furthermore, studies on diurnal patterns of rumen fermentation and the effect of rumen digesta transfer from buffalo to cattle was conducted. Based on these studies, diurnal fermentation patterns in both cattle and buffaloes were revealed. It was found that rumen NH_3-N was a major limiting factor. Rumen digesta transfer from buffalo to cattle from buffalo to cattle was achievable. Monitoring rumen digesta for 14d after transfer showed an improved rumen ecology in cattle as compared to that of original cattle and buffalo. It is probable that buffalo rumen digesta could be transferred. However, further research should be undertaken in these regards in order to improve rumen ecology especially for buffalo-based rumen. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 4 : 504-510)***

Key Words : Swamp Buffalo, Beef Cattle, Rumen Ecology, Rumen Microorganisms, Manipulation, Digesta Transfer, Rice Straw

INTRODUCTION

The rumen has been well recognized as an essential fermentation vat that is capable of supplying end-products particularly volatile fatty acids (VFAs) and microbial proteins as major energy and protein for the ruminant host. The more efficient the rumen is the better the fermentation end-products being synthesized. In recent years, there has been increasing research directed towards rumen ecology and rumen manipulation (Ørskov and Flint, 1989; Martin, 1998; Weimer, 1998). However, most of these papers have dealt with ruminants raised in temperate areas and fed on good-quality roughages and with high levels of concentrate supplementation. However in the tropics, most ruminants are fed on low-quality roughages, agricultural crop-residues/and industrial by-products which contain high levels of ligno-cellulosic materials, a low level of fermentable carbohydrate and a low level of good-quality protein. In addition, long dry seasons, a prevailing harsh environment, high temperatures, low soil fertility and low feed availability throughout the year, all adversely influence rumen microbes and fermentation (Wanapat et. al., 2000c). Recently, Wanapat (2000) reported on rumen fermentation to increase the efficient use of local feed resources and productivity of ruminants in the topics (Kennedy and Hogan, 1994). Nitrogen utilization in swamp buffalo was found to be more efficient than that in Malaysian cattle (Devendra, 1985). This superiority is particularly noticeable in situations where the feed supply is of low quantity and/or quality. The reasons for the superior digestive capacity of buffalo over cattle have not been fully elucidated. However it is likely that much of the superiority may be explained by differences in the nature of rumen microbial population which would affect the type of fermentation occurring and the end-products resulting from fermentation. Thus, any variations between cattle and buffalo in the proportions and numbers of ruminal bacteria, protozoa and fungi might contribute to the explanation of differences in digestive capability due to fermentation end-products available for absorption and utilization by ruminants.

The objectives of these experiments were to identify the rumen fermentation pattern in buffalo and cattle fed on untreated and urea-treated rice straw and to investigate the feasibility and practicality of rumen digesta transfer.

MATERIALS AND METHODS

Digestion trial

Rumen-fistulated buffaloes and cattle (3 of each) with average weight of 450 and 250 kg, age of 4 and 3 years, respectively, were randomly assigned according to a 3×3 Latin square design to receive three roughage sources and the treatments were as follows:

RS = untreated rice straw
UTRS = urea-treated (5%) rice straw
MX = RS and UTRS (1:1) (DM basis)

All animals received the roughage on an ad libitum basis and in addition rice bran was supplement at 0.5% of body weight. Each stage of the feeding trial lasted for 21 days. Feed intakes were measured during the first two weeks and were followed by a 24-h rumen fluid sampling for every

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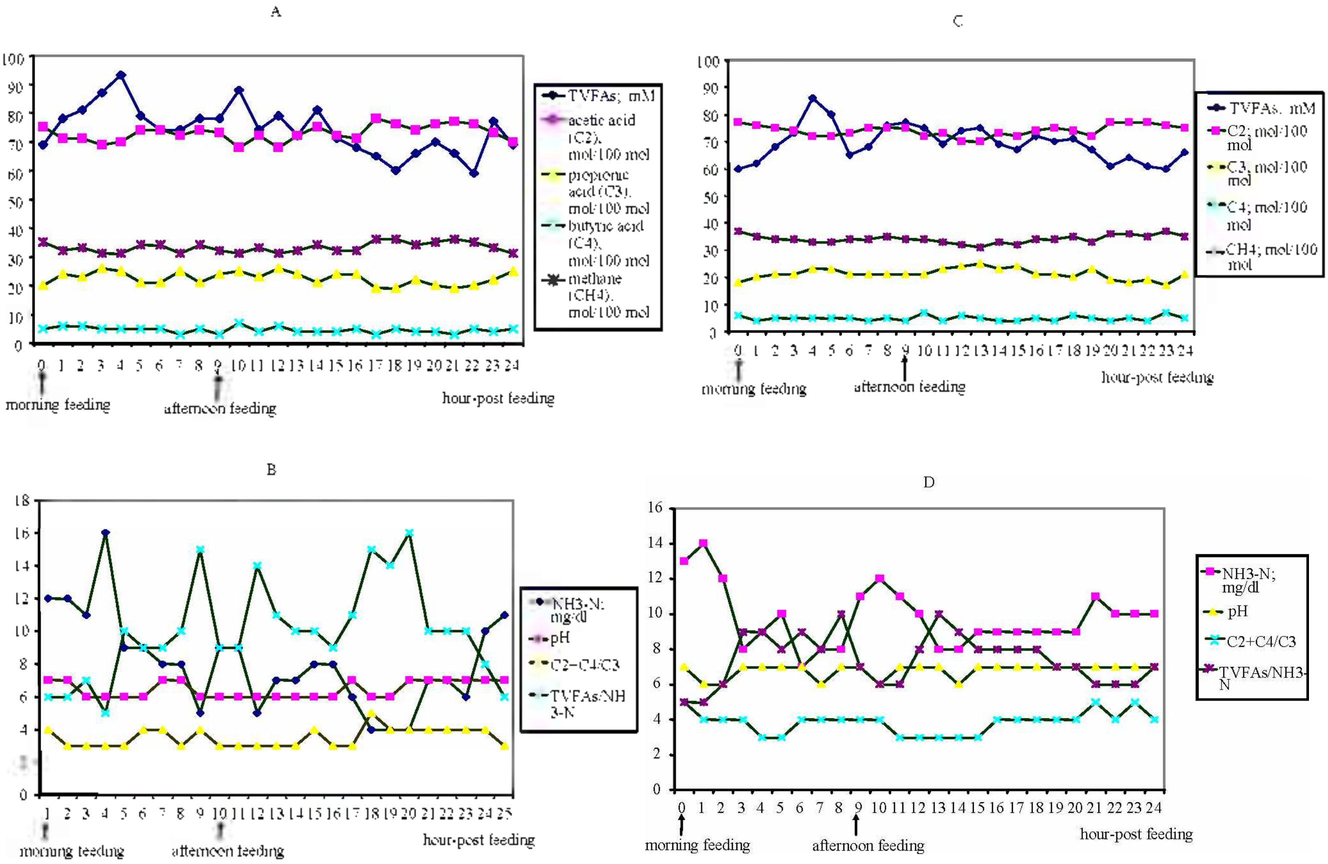

Figure 1. Diurnal rumen characteristics of cattle and buffalo fed on rice straw (RS).
A, B = cattle fed on RS; C, D = buffalo fed on RS

hour. Samples were measured for pH immediately and prepared for later analyses of NH_3-N, VFAs, total viable counts of cellulolytic, proteolytic and amylolytic bacteria. During last five days, animals were placed on metabolism crates for total collection of feed, faces and urine. Animals were fed 90% of previous days feed intakes. Calculations of apparent digestibilities for the three feeds using total collection method were done according to a 3×3 Latin square design, prior to the rumen digesta transfer study.

Rumen fluid was collected at 0 and 4 h-post feeding and measured immediately for pH and samples were prepared for later analysis of NH_3-N (Bromner and Keeney, 1965), volatile fatty acids (VFAs) using HPLC (Samuel et al., 1997), total viable cellulolytic, proteolytic and amylolytic bacteria were measured using the roll tube technique (Hungate, 1969). Digestibilities of nutrients were calculated. All data were subjected to ANOVA and treatment means comparisons were conducted by Duncan's New Multiple Range Test using Proc GLM (SAS, 1985).

Digesta Transfer Study : All rumen fistulated buffaloes and cattle (3 of each) were fed with three kinds of roughage treatments using a 3×3 Latin square design: untreated rice straw (RS), urea-treated (5%) rice straw (UTRS) or RS and UTRS (1:1) (MX). They were fed for two weeks and then rumen fluid were collected at 0, 4 h-post feeding. Measurements of pH were taken immediately while other rumen fluid samples were treated and prepared for later analyses of NH_3-N (Bromner and Keeney, 1965), volatile fatty acids (VFAs) using HPLC as the above. Total viable cellulolytic, proteolytic and amylolytic bacteria were counted using roll tube technique (Hungate, 1969).

After the initial sampling period (3 weeks), the rumen digesta (about 50% by weight of total digesta) from each buffalo fed on each respective roughage were transferred to cattle which had received the corresponding roughage after rumen digesta of the cattle had been removed completely. These transfer were done as quickly as possible to avoid extended exposure of digesta to the air. After completed transfer, all lids of fistulae were closed. Sampling of rumen fluid were taken at 0, 4 h post feeding, before transfer, and 7

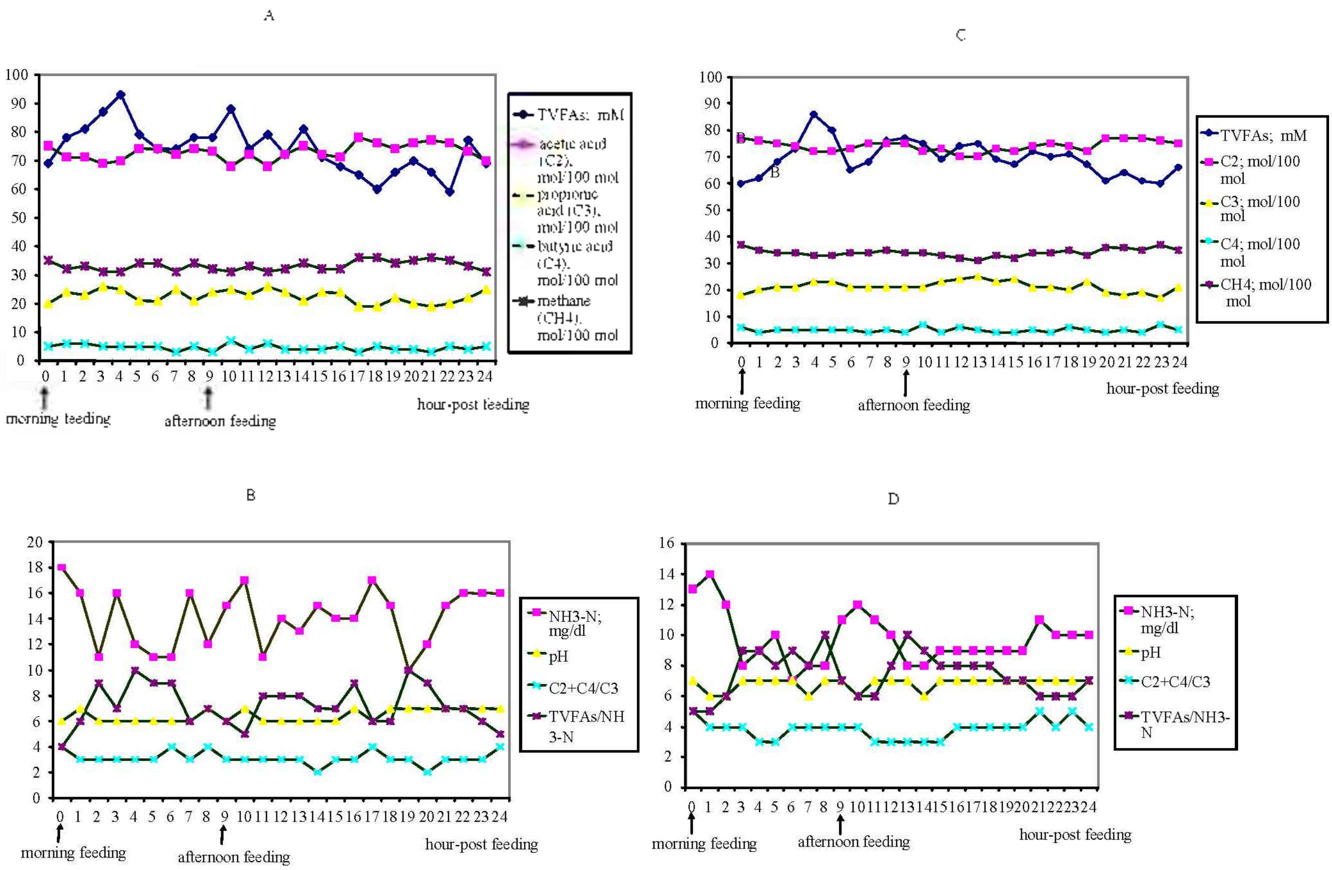

Figure 2. Diurnal rumen characteristics of cattle and buffalo fed on urea treated-rice straw (UTS).
A, B=cattle fed on UTS; C, D=buffalo fed on UTS

and 14 days after rumen digesta transfer to be measured for rumen pH, NH_3-N, VFAs and total viable counts of cellulolytic, proteolytic and amylolytic bacteria using standard methods as indicated above. All data were subjected to ANOVA and treatment means were compared sing Duncan's New Multiple Range Test (Proc. GLM, SAS, 1985).

RESULTS AND DISCUSSION

Diurnal variations of rumen fermentation characteristics in ruminants fed on rice straw

The diurnal patterns of rumen fermentation characteristics were studied in beef cattle and swamp buffaloes fed on untreated and urea-treated rice straw. In both cattle and buffaloes, rumen pH and temperature were maintained and the values were 6.5-6.7; 38-39°C, respectively. However, VFA production patterns fluctuated in acetate concentration while of propionate and butyrate were similar indicating an active role of rumen microbes and on-going fibre fermentation by cellulolytic bacteria. It was also found that rumen NH_3-N was consistent and relatively low (<5 mg/dl) throughout the period. However, all of the fermentation aspects except rumen pH and temperature were notably enhanced by feeding urea-treated rice straw (Figures 1, 2, 3). Rumen fermentation end-products were significantly different as a result of feeding different types of roughage. As shown in Table 2 rumen NH_3-N, acetate, propionate were increased with urea-treated rice straw and were also higher in buffalo than in cattle. When taken acetate+butyrate/propionate ($C2+C4/C_3$), TVFA/NH_3-N were also narrower (based on values in Table 4). Based on this study, low rumen NH_3-N could be a limiting factor on rumen fermentation and would ultimately affect rumen ecology.

In ruminants fed on low-quality roughages, critical rumen NH_3-N levels for microbial activities were found at 5-20 mg/dl (Boniface et al., 1986; Perdok and Leng, 1989). While Chanthai et al. (1987) demonstrated that rumen NH_3-N in cattle and buffaloes fed on untreated rice straw were less than 2 mg/dl and were increased to 9 mg/dl with urea-treated rice straw. Perdok and Leng (1989) further showed that higher level of rumen NH_3-N (15-30 mg/dl) improved intake and digestibility. Increasing rumen NH_3-N level up to 30 mg/dl significantly decreased C_2+C_4/C_3, increased rumen fungal zoospores and increased microbial protein synthesis (17-

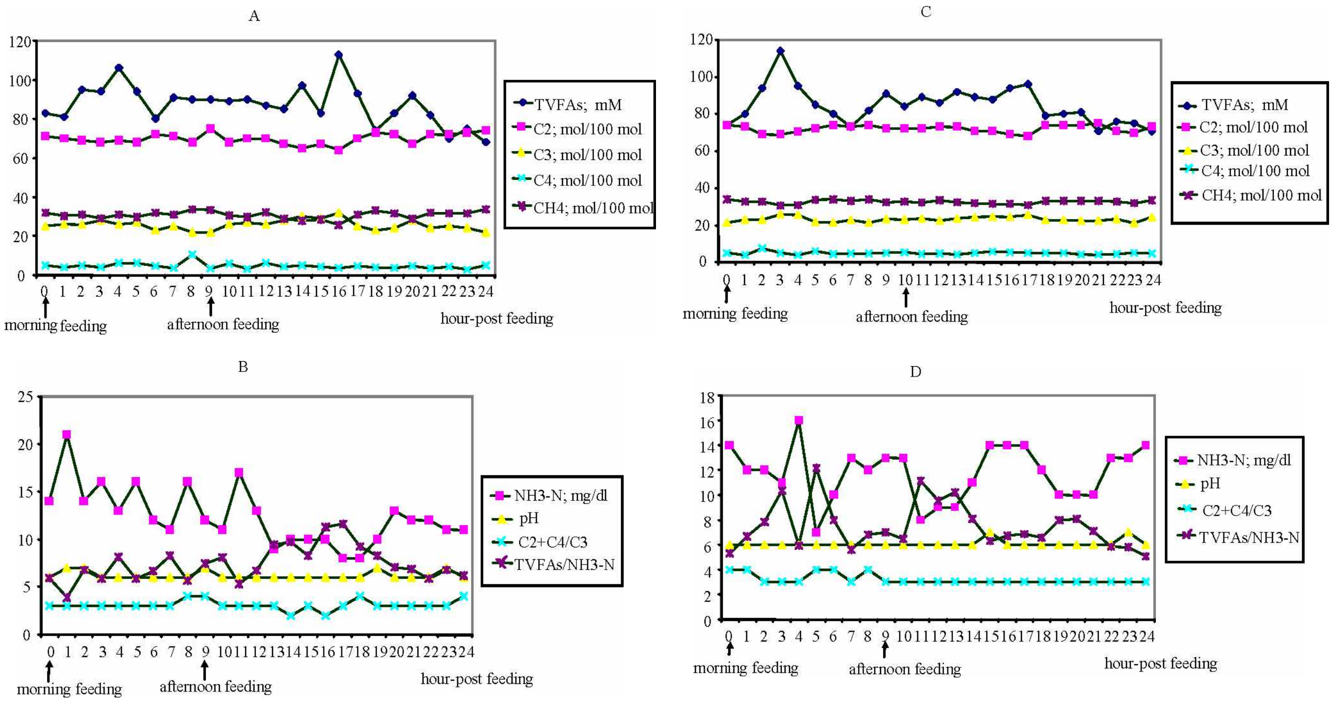

Figure 3. Diurnal rumen characteristics of cattle and buffalo fed on RS and UTS (MX)
A, B=cattle fed on MX; C, D=buffalo fed on MX.

47%) (Kanjanapruthipong and Leng, 1998). Swamp buffaloes fed on untreated rice straw. Wanapat and Pimpa (1999) also found similar results that rumen NH_3-N levels of 13.6-34.4 mg/dl improved rumen fermentation by increasing digestibility and intake of straw. As rumen NH_3-N increased, rumen bacteria and protozoa, as well as urinary purines were also increased. It was suggested that optimum rumen NH_3-N level would be higher than 15 mg/dl. Nguyen and Preston (1999) also found rumen NH_3-N (5-6 mg/dl) of swamp buffaloes fed on rice straw or grass and were significantly increased to 8-18 mg/dl by adding urea-treated rice straw, urea-molasses cake and Sesbania leaf. The increases in rumen bacterial, protozoal population as well as DMI were also concomitantly found with increases in NH_3-N in rumen.

Effect of buffalo rumen digesta transfer

Table 1 presents the chemical composition of the experimental feeds. Apparent digestibilities are shown in Table 2. As presented, urea-treated rice straw (UTRS) digestibilities were the highest of the three feed treatments ($p<0.05$) and digestibilities of nutrients particularly those of organic matter and crude protein were higher in buffalo than cattle. Several factors have been suggested to attribute to these values.

Intakes of roughages were highest in both cattle and buffaloes fed on UTRS in terms of kg/d, %BW, g/kgW$^{.75}$. In general, intakes of these roughages before and buffalo digesta transfer were similar at 7 and 14 days after transfer (Table 3).

Digesta transfer did not show effect on rumen pH in all treatments and were in the normal range of rumen ecology (pH 6.2-6.7). Rumen NH_3-N concentrations were lowest in

Table 1. Chemical compositions (%DM) of experimental feeds

Item	DM	OM	CP	NDF	ADF	Ash
Rice straw (RS)	92.8	88.6	3.4	76.9	48.9	11.4
Urea-treated rice straw (UTRS)	55.2	88.1	7.5	68.3	42.2	11.9
RS+UTRS (1:1)	79.0	88.7	5.3	73.4	46.4	11.3
Extracted rice bran	90.2	84.7	14.2	12.4	4.5	15.4

DM=dry matter, OM=organic matter, CP=crude protein
NDF=neutral-detergent fiber, ADF=acid-detergent fiber

Table 2. The apparent digestibility (%) of feeds in cattle and swamp buffaloes receiving the same feeds

Item	Treatments						SEM
	RS		UTRS		MX		
	C	B	C	B	C	B	
Apparent digestibility, %							
DM	50.4^{a}	54.4^{a}	63.7^{b}	63.1^{b}	55.8^{ab}	57.9^{ab}	1.3
OM	51.9^{a}	57.3^{ab}	64.3^{b}	68.4^{b}	61.9^{b}	62.2^{b}	1.2
CP	35.4^{a}	33.7^{a}	49.7^{ab}	55.9^{b}	43.4^{ab}	41.1^{ab}	2.5
NDF	35.4^{a}	36.5^{a}	50.6^{b}	51.2^{b}	46.6^{ab}	47.8^{ab}	2.9
ADF	45.1	41.6	52.4	55.3	47.7	47.8	5.0

^{a,b} values on the same row with different superscripts differ ($p<0.05$)
DM=dry matter, OM=organic matter, CP=crude protein
NDF=neutral-detergent fiber, ADF=acid-detergent fiber
RS=rice straw, UTRS=urea-treated rice straw
MX=RS+UTRS (1:1)
C=cattle, B=buffaloes
SEM=standard error of the mean

Table 3. Effect of rumen digesta of buffalo transfer into cattle on feed intake.

	Before		Digesta transfer After 7 d		After 14 d		SEM
	C	B	C	B	C	B	
Total DM intake, kg/d							
RS	4.1	5.5	4.5	5.5	4.0	5.3	0.6
UTRS	5.1	6.5	5.3	5.7	5.3	5.5	0.5
MX	5.2	5.6	5.7	5.9	6.0	5.8	0.5
%BW							
RS	1.2	1.4	1.2	1.2	1.4	1.3	0.1
UTRS	1.8	1.9	1.9	2.1	2.0	1.7	0.3
MX	1.3	1.5	1.7	1.5	1.4	1.9	0.1
$g/kgW^{0.75}$							
RS	72.8	81.5	73.5	83.3	77.2	84.2	8.0
UTRS	86.1	102.1	87.5	92.5	97.5	92.6	10.3
MX	93.9	84.2	93.4	88.3	96.7	84.2	3.2

RS=rice straw, UTRS=urea-treated rice straw, MX=RS+UTRS (1:1)
C=cattle, B=buffaloes
SEM=standard error of the mean

Table 4. Effect of rumen digesta of buffalo transfer into cattle on rumen pH, NH_3-N, total volatile fatty acid (TVFA), acetic acid (C2), propionic acid (C3) and butyric acid (C4)

Items	Before		Digesta transfer After 7 d		After 14 d		SEM
	C	B	C	B	C	B	
Rumen pH							
0 h postfeeding							
RS	6.4	6.3	6.6	6.7	6.5	6.6	0.06
UTRS	6.4	6.1	6.4	6.3	6.6	6.6	0.08
MX	6.2	6.4	6.4	6.8	6.5	6.4	0.08
4-h-postfeeding							
RS	6.5	6.3	6.3	6.3	6.5	6.7	0.05
UTRS	6.4	6.2	6.1	6.1	6.5	6.6	0.07
MX	6.6	6.5	6.2	6.3	6.5	6.5	0.06
NH3-N, mg%							
0 h postfeeding							
RS	3.1^{a}	5.4^{ab}	3.8^{a}	6.5^{b}	5.8^{b}	6.6^{b}	0.6
UTRS	11.9^{ab}	12.8^{ab}	8.9^{a}	11.7^{ab}	15.1^{b}	13.9^{a}	0.9
MX	11.6^{ab}	9.5^{ab}	7.9^{a}	8.9^{ab}	7.9^{a}	13.5^{b}	0.9
4-h postfeeding							
RS	6.4	6.3	6.9	7.4	5.1	6.5	0.3
UTRS	13.0^{ab}	10.9^{ab}	15.2^{b}	10.0^{ab}	9.6^{a}	13.9^{b}	0.9
MX	9.8	8.9	8.4	7.5	7.1	7.5	0.4
TVFA, mM							
0-h-postfeeding							
RS	85.9	85.7	86.7	78.4	102.1	83.2	14.2
UTRS	94.6	106.9	112.7	116.8	125.3	101.9	11.6
MX	91.5	104.2	110.9	99.5	99.6	85.8	9.1
4-h-postfeeding							
RS	75.7	80.5	100.2	94.2	112.2	85.1	10.5
UTRS	104.4	120.9	117.9	119.3	104.3	115.9	12.2
MX	118.6	107.6	109.7	100.3	104.6	96.5	10.0

ab values on the same row with different superscripts differ ($p<0.05$)
RS=rice straw, UTRS=urea-treated rice straw
MX=RS+UTRS (1:1)
C=cattle. B=buffaloes, SEM=standard error of the mean

animals fed on untreated rice straw (RS) and highest in UTRS fed groups. These NH_3-N values remained low in RS fed group after buffalo digesta transfer at 7 and 14 d, respectively and were lower than those reported as optimal (20-30 mg%) (Boniface et al., 1989; Perdok and Leng, 1989; Wanapat and Pimpa, 1999). Values in cattle and buffalo fed on UTRS and the forage mixture of RS+UTRS (MX) were found to be higher and were maintained after digesta transfer for 14 d. Values at 4 h-post feeding showed a trend towards elevated values (Table 4).

Total volatile fatty acids (TVFAs) at 0 h post-feeding were highest in UTRS and in buffaloes, while at 4 h-post feeding they were higher in amounts fed UTRS and MX. At 7 and 14 d after digesta transfer, TVFAs of cattle were comparable to those of buffaloes. This could be an attributing factor from digesta transfer. For C_2, C_3 and C4, all values were similar both. before and after 7, 14 d digesta transfer for both cattle and buffaloes. It is noticeable that C_3

Table 5. Effect of rumen digesta of buffalo transfer into cattle on rumen pH, NH_3-N, total volatile fatty acid (TVFA), acetic acid (C2), propionic acid (C3) and butyric acid (C4)

Items	Before		Digesta transfer After 7 d		After 14 d		SEM
	C	B	C	B	C	B	
Acetic acid (C_2), mM							
0 h postfeeding							
RS	67.2	64.6	66.2	68.4	69.3	65.7	5.4
UTRS	70.8^{b}	68.8^{ab}	64.2^{ab}	67.4^{ab}	62.9^{a}	70.8^{b}	2.7
MX	65.3^{ab}	67.9^{ab}	70.4^{a}	68.6^{ab}	62.4^{b}	68.8^{ab}	3.0
4h postfeeding							
RS	68.7	69.2	67.1	68.8	66.1	69.7	3.8
UTRS	70.5	68.9	66.6	67.6	66.8	69.5	3.7
MX	68.7	66.9	68.7	72.7	66.6	69.2	3.6
Propionic acid (C_3), mM							
0 h postfeeding							
RS	26.2	29.8	23.9	24.2	22.4	24.6	4.3
UTRS	24.0	27.6	29.3	27.8	25.4	23.4	3.5
MX	26.9	23.2	24.8	24.6	29.5	25.8	3.5
4 h postfeeding							
RS	25.2	26.8	26.5	24.4	28.0	26.3	3.9
UTRS	21.9	25.7	28.1	26.6	26.3	24.1	2.9
MX	23.5	26.4	24.4	26.6	31.1	28.8	4.3
Butyric acid (C_4), mM							
0 h postfeeding							
RS	4.7	5.6	9.8	7.3	8.0	9.6	2.6
UTRS	5.2^{a}	6.9^{ab}	6.9^{ab}	4.8^{a}	11.7^{b}	6.2^{a}	2.1
MX	7.9	8.9	8.1	10.1	8.1	5.4	2.0
4 h postfeeding							
RS	6.0	7.3	6.3	6.8	6.0	7.3	1.7
UTRS	7.5	5.3	6.1	5.8	6.9	8.0	1.6
MX	7.8	6.6	6.9	4.7	5.7	5.9	2.0

ab values on the same row with different superscripts differ (<0.05)
RS = rice straw, UTRS = urea-treated rice straw
MX=RS+UTRS (1:1)
C=cattle, B=buffaloes
SEM=standard error of the mean.

Table 6. Effect of rumen digesta of buffalo transfer into cattle on rumen microorganisms

Items	Before		Digesta transfer				SEM
			After 7 d		After 14 d		
	C	B	C	B	C	B	
Total viable bacteria, 10^{11}CFU/g							
0 h postfeeding							
RS	2.1^{a}	2.9^{ab}	2.4^{a}	4.6^{ab}	3.4^{ab}	5.7^{b}	0.9
UTRS	2.3^{a}	3.0^{ab}	3.4^{ab}	3.8^{ab}	4.2^{ab}	4.8^{b}	0.7
MX	2.6^{a}	2.8^{a}	5.0^{ab}	2.4^{a}	3.4^{ab}	5.8^{b}	0.8
4 h posfeeding							
RS	1.2^{a}	2.8^{ab}	4.5^{bc}	4.8^{bc}	5.6^{c}	5.1^{c}	0.6
UTRS	2.8^{a}	3.2^{a}	5.9^{b}	5.2^{ab}	4.7^{ab}	5.0^{ab}	0.8
MX	3.6	3.6	4.6	4.8	3.5	5.3	1.4
Cellulolytic bacteria, 10^{10}CFU/g							
0 h postfeeding							
RS	1.8^{a}	2.8^{ab}	3.1^{ab}	4.2^{b}	2.2^{a}	2.5^{ab}	0.6
UTRS	3.4	5.9	2.7	2.7	5.1	5.7	1.9
MX	1.9^{a}	4.1^{b}	2.6^{ab}	3.0^{ab}	4.5^{b}	2.3^{a}	0.6
4 h postfeeding							
RS	2.9^{a}	3.5^{ab}	3.4^{ab}	5.2^{b}	3.1^{a}	3.3^{ab}	0.6
UTRS	4.5^{a}	10.5^{b}	5.4^{ab}	7.1^{ab}	5.1^{ab}	4.5^{a}	1.4
MX	2.5	5.2	3.2	6.5	3.4	2.5	1.0
Proteolytic bacteria, 10^{7}CFU/g							
0h postfeeding							
RS	1.5^{a}	2.7^{a}	2.6^{a}	7.1^{b}	4.6^{ab}	2.5^{a}	0.6
UTRS	2.7^{a}	4.2^{ab}	5.2^{ab}	8.2^{b}	5.2^{ab}	5.9^{ab}	1.1
MX	3.8	4.2	3.6	3.9	3.6	3.7	0.9
4 h postfeeding							
RS	2.8	2.3	3.4	3.2	5.0	2.5	1.4
UTRS	2.4	5.7	5.2	8.8	6.6	3.5	1.8
MX	4.4	2.5	4.6	3.2	2.8	2.4	0.6
Amylolytic bacteria, 10^{7}CFU/g							
0 h post feeding							
RS	2.6^{a}	3.0^{ab}	4.0^{b}	2.5^{a}	3.7^{ab}	4.0^{b}	0.9
UTRS	3.5	3.6	4.3	5.3	5.4	3.9	0.8
MX	3.2^{ab}	2.9^{a}	3.9^{ab}	2.7^{a}	5.8^{b}	3.3^{ab}	0.7
4h postfeeding							
RS	3.1	3.2	3.2	2.7	4.4	3.7	0.7
UTRS	3.5	5.3	4.9	4.9	3.8	5.6	0.9
MX	4.3^{ab}	5.9^{ab}	4.9^{ab}	7.3^{b}	4.0^{ab}	3.2^{a}	1.0

^{a,b,c} values on the same row with different superscripts differ ($p<0.05$)
RS=rice straw, UTRS=urea-treated rice straw
MX=RS+UTRS (1:1)
C=cattle. B=buffaloes
SEM=standard error of the mean

concentrations were relatively high in all fed groups (Table 5).

Effect of digesta transfer on rumen microorganisms : Total viable bacteria counts were found to be similar for all treatments and sampling times. However, the values found to be in buffaloes and UTRS were generally higher than cattle on RS or MX fed group. Cellulolytic, proteolytic and amylolytic bacterial counts of cattle were increased at 7 and 14 d after digesta transfer. The highest values were obtained in buffalo fed on UTRS and particularly at 7 d after digesta transfer. This could mean that after removal of digesta, buffalo rumen could still have functionally higher rumen turn over rates while in cattle, digesta transfer could be sustainable as seen by the values 14 d after transfer (Table 6).

Other means of manipulating the rumen could be used e.g. condensed tannins. Condensed tannins contained in cassava hay has been shown to modify rumen microorganisms. fermentation and to enhance rumen by-pass protein (Wanapat, 2,000; Wanapat et al., 1999, 2000a, b)

Diurnal fermentation pattern was monitored and rumen NH_3-N appeared to be the limiting factor when animals were fed on straw. UTRS resulted in a higher nutritive value than RS or MX. Rumen digesta transfer from buffalo to cattle could be achieved. The results in terms of intake, digestibility and rumen ecological parameters appear to be sustainable. However, longer periods of study and more work on rumen microorganisms should be conducted to elucidate more details for possible recommendations and implementations.

Based on this study, swamp buffalo and cattle fed on rice straw based-diets exhibited steady diurnal rumen fermentation patterns with a lower rumen NH_3-N concentration relatively to VFA production (Figures 1, 2, 3). It was therefore, concluded supplementation for higher rumen NH_3-N especially from NPN like urea could effectively improve rumen ecology and subsequent fermentation.

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