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Effect of varying energy density on feed intake, digestibility of nutrients and fermentation pattern in Swamp buffaloes fed on rice straw and concentrate-based diets

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ABSTRACT

The aim of this study was to investigate the effect of energy (TDN) level for optimum to improve nutrients, feed intake and feed digestibility in swamp buffaloes (*Bubalus bubalis*) fed on rice-straw-based-diet. Four, rumen-fistulated swamp buffalo bulls (4-year old) with 401±4 kg live weight were randomly assigned to receive 4 dietary treatments according to a 4×4 Latin square design. Four levels of energy (74, 76.1, 80.6 and 84.3% TDN), 12.1% CP in concentrate mixtures were fed to buffaloes with rice-straw as a roughage. The results revealed that voluntary dry matter feed intake and nutrient digestibility were altered among energy levels of the concentrate supplements. The level of TDN in the supplements had influenced on rumen pH, but not ammonia-nitrogen, blood-urea nitrogen and rumen temperature. Rumen concentrations of propionate (C_3) and butyrate (C_4) were significantly different between the 76.1 to 80.6 and 76.1 to 84.3%TDN, respectively, while total volatile fatty acids (VFAs), acetate and C_2: C_3 ratio was not altered. However, digestibilities of OM improved with concentrate containing 76.1 and 80.6% TDN, while CP improvement was higher at 76.1%TDN. Moreover, nitrogen urinary and purine derivatives (PD) excretion were significantly different between the 76.1 and 76.1 to 80.6%TDN, respectively, while PD absorption and efficiency of microbial N synthesis showed significant improvements by the use of 76.1%TDN. Based on this result, the TDN % of concentrate response at 76.1–80.6% should be recommended, when used with rice straw in buffalo.

Key words: Energy density, Feed intake, Nutrient digestibility, Swamp buffalo

Swamp buffaloes (*Bubalus bubalis*) are able to utilize low-quality roughages and crop-residues. These low quality feeds are primarily deficient in nitrogen and energy therefore, energy supplementation is essential in enhancing digestibility and intake of the basal roughages (Ørskov 1986, Fonseca *et al*. 2001). However, there are indications that the responses in digestibility and intake of poor quality basal roughage to energy supplementation were variable and influenced by type, form and amount of energy supplement, relative proportion as well as the quality of the basal roughage (Obara *et al*. 1991). Swamp buffaloes fed on rice straw and cassava chip showed that cassava chip was a good energy source with faster degradation in the rumen (Wanapat 2009). ATP is important in improving the efficiency of rumen N utilization (Nocek and Tamminga 1991, NRC 2001).

Although, a few studies have been conducted to evaluate effects of dietary TDN or energy in concentrate supplementation in swamp buffaloes, but the data are relatively limited and inconclusive. Therefore, the aim of this study was to investigate the effect of varying energy (TDN) levels on feed intake, nutrient digestibility and fermentation pattern in swamp buffaloes (*Bubalus bubalis*) fed on rice straw based diet.

MATERIALS AND METHODS

Animals, diets and experimental design: Four, ruminally fistulated male or female swamp buffalo (breed) with initial body weight (BW) of 401±4 kg were randomly assigned to a 4×4 Latin square design. All the animals were fed on a basal diet comprising paddy straw (*ad lib.*) and concentrate (1% of BW). The TDN (%) level was maintained as 74 (T_1 as control), 76.1 (T_2), 80.6 (T_3) and 84.3 (T_4)% by varying the levels of ingredients of concentrate mixture for different

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Table 1. Ingredients and chemical composition of the concentrates

Item	Treatments,%TDN				RS
	T1	T2	T3	T4	
Cassava chip	45	50	55	60	-
Rice bran	24	15	5	3	-
Coconut meal	5	5	15	15	-
Palm kernel meal (PKM)	19.5	17	10	2	-
Soybean meal	1	7	5	6	
Tallow	0.5	1	3	5	-
Molasses	0.5	1	3	5	-
Urea	1.5	1	1	1	-
Premix	1	1	1	1	-
Sulfur	1	1	1	1	-
Salt	1	1	1	1	-
Total parts	100	100	100	100	-
Chemical composition % of dry matter (DM)					
TDN*	74	76.1	80.6	84.3	47
CP	12.2	12.1	12.4	12	2.7
NDF	41	35.5	32	27.1	72.7
ADF	15.1	14.6	15.8	12.3	43.2

T1: 74, T2: 76.1, T3: 80.6, T4: 84.3% TDN, TDN, total digestible nutrient; estimated value; RS, rice straw; DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral-detergent acid fibre; ADF, acid-detergent fibre.

groups. The CP level for different groups was around 12.1%. All buffaloes were kept in individual pens, clean freshwater and mineral blocks were available at all times. The experiment consisted of 4 periods, and each period lasted for 21 days including 14 days preliminary feeding and thereafter 7 days metabolism trial. The chemical composition of concentrates and rice straw is given in Table 1.

Chemical analyses and sample collection: Feed, refusal and fecal samples were collected during the 7 days metabolism trial and in the end all the samples within a group were pooled, grind and analyzed for chemical composition, viz. moisture, ash, CP and NH_3-N as per AOAC (1995), while NDF, ADF in the samples were determined according to Van Soest *et al*. (1991).

Rumen fluid samples from male fistulated animals were collected at 0, 2, 4 and 6 h post-feeding through rumen fistula (for how many days, collection was made). The pH and temperature of the collected rumen liquor was measured immediately after collection. Rumen fluid used to determine volatile fatty acids in the rumen liquor were determined in the liquor samples as per Samuel *et al.* (1997) using High performance liquid chromatography. Blood samples (about 10 ml) from jugular vein were collected into EDTA containing tubes at the above defined period. The blood samples were centrifuged at 500 × g, 10 min, and 4°C to sequent blood which was stored at –20°C until analysis of blood urea N according to Crocker (1967). Urine samples were analyzed for allantoin, and creatinine in urine by HPLC (Chen and Gomes 1995). The amount of microbial purines absorbed was calculated from purine derivative excretion based on the relationship derived by Chen and Gomes (1995).

Statistical analysis: All data were statistically analyzed according to a 4×4 Latin square design using SAS (1996) GLM procedure following the model:

$$Y_{ijk} = \mu + T_i + C_j + R_k + e_{ijk}$$

Y_{ijk}, observation from swamp buffalo j, receiving diet i, in period k; μ, the overall mean, M_i, effect of the different N sources (i=1, 2, 3, 4), A_j, the effect of swamp buffalo (j=1, 2, 3, 4), P_k, the effect of period (k = 1, 2, 3, 4), and ε_{ijk}, residual effect.

Differences between treatment means were determined by Duncan's new multiple range test (Steel and Torrie 1980) with P<0.05 level of significance.

Table 2. Rumen pH, temperature, ammonia- nitrogen (NH_3-N), blood-urea nitrogen (BUN) and VFA concentrations in swamp buffaloes fed with different levels of TDN supplementation

Items	Treatments,%TDN				SEM	P-value
	T1	T2	T3	T4		
Rumen parameters						
pH	6.5[b]	6.3[b]	6.3[b]	6.2[a]	0.1	0.05
Temperature, °C	39.4	39.6	39.7	39.6	0.14	0.72
NH_3-N, mg%	11.2	11.8	12.3	11.3	0.74	0.68
BUN, mg%	9.0	9.5	8.5	8.0	0.84	0.64
Total VFA, mM/ml						
VFA, mol/100 mol	93.1	100.7	99.8	102.2	2.3	0.12
C_2	60.8	68.7	63.8	65.2	1.9	0.13
C_3	20.7[a]	23.1[b]	22.9[b]	22.3[ab]	0.5	0.05
C_4	11.2[a]	12.7[ab]	13.3[b]	14.4[b]	0.6	0.05
C2/C3	3	2.8	2.8	2.9	0.1	0.28

[a,b]Means in the same row with different superscripts differ (P<0.05), BUN, blood urea nitrogen; VFA, volatile fatty acid; L, linear; Q, quadratic; C, cubic; C2, acetic acid; C3, propionic acid; C4, butyric acid; C2/C3, concentration of acids acetic acid to propionic ratio; T1: 74; T2: 76.1; T3: 80.6; T4: 84.3% TDN; SEM, standard error of the mean.

RESULTS AND DISCUSSION

Chemical composition: Concentrate diets contained 74, 76.1, 80.6, and 84.3%TDN and 12.2, 12.1, 12.4 and 12%CP on a DM basis for the 4 respective treatments while rice straw (RS) contained 72.7% NDF and 2.7% CP on a DM basis. Chemical composition of rice straw was in similar range as reported by Wanapat (2000).

Feed intake and digestibility: The effects of various TDN levels on feed intake and digestibility of nutrients in buffalo fed on rice straw based diets are presented in Table 3. DM intake (kg/d) revealed significant ($P<0.05$) improvements in group T_2 when compared with control and other treatments, while, nutrient and estimated energy intake were significantly ($P<0.05$) improved in OM and ME intake by using 76.1 and 80.6% TDN, respectively. However, the apparent digestibility resulted in significant ($P<0.05$) improvements in OM with concentrate containing 76.1 and 80.6%TDN, while CP improvement was higher at 76.1% TDN, when fed on rice straw based-diet. This study agreed with the result of Mahmoudzadeh *et al*. (2007) who found no effect of protein level on feed intake while energy levels significantly ($P<0.05$) affected on the DMI in male buffalo calves. Besides, the physical and chemical characteristics of feed (Barman and Mohini 2002), energy concentration in the diets could influence on dry matter intakes of the ruminants (Baruah *et al*. 1988, Nair *et al*. 2004, Puri *et al*. 2004). Similar trend was reported by Baruah (1990) in Indian growing buffalo calves fed on concentrate and wheat straw.

However, Baruah *et al.* (1988) did not find any significant effect of energy levels on nutrients utilization in the Murrah buffalo calves. Carey *et al.* (1993) reported that higher rumen fermentable energy could increase OM digestibility in animals fed on sugar beet pulp and corn based ration. It suggests that higher level of TDN in concentrate could have a subsequent impact on decreasing rice straw digestibility. This suggestion was also supported by Ahmet *et al.* (1998) who reported a depression in CP and CF digestibilities with the addition of molasses into barely straw based-diet.

Rumen fermentation parameters and blood metabolites: The rumen fermentation pattern and blood urea N was also determined to investigate relationship (Table 2). Rumen fluid pH was lower ($P<0.05$) in high carbohydrate level, while temperature, NH_3-N and blood urea N were not altered among treatments and the values were relatively stable around pH 6–6.5. In addition, propionic acid (C_3) and butyric acid (C_4) were found higher ($P<0.05$) in groups the 76.1 to

Table 3. Influence of TDN levels on voluntary feed intake and nutrient digestibility in swamp buffaloes

Items	Treatments,%TDN				SEM	P-value
	T1	T2	T3	T4		
ADG, g/d	280	750	330	280	0.33	0.69
Rice straw DM intake						
kg/d	5.5	5.6	5.5	5.4	0.34	0.98
%BW	1.2	1.4	1.3	1.1	0.1	0.25
Concentrate DM intake						
kg/d	3.5	3.7	3.6	3.5	0.26	0.89
%BW	0.8	0.9	0.8	0.8	0.1	0.27
Total DM intake						
kg/d	8.9^{ab}	9.5^{b}	9.4^{ab}	8.5^{a}	0.3	0.05
%BW daily	2.1^{ab}	2.3^{a}	2.1^{ab}	1.9^{b}	0.1	0.05
Nutrient intake, kg/d						
OM	7.9^{a}	8.9^{b}	8.8^{b}	8.2^{a}	0.17	0.006
CP	2.2	2.3	2.3	2.2	0.1	0.73
NDF	8.4	8.3	9.1	8.5	0.5	0.64
ADF	5.0	5.3	5.4	5.1	0.3	0.62
Estimated energy intake[1]						
ME, Mcal/d	30.1^{a}	34.1^{b}	33.5^{a}	31.1^{a}	0.6	0.003
ME, Mcal/kg DM	2.1^{a}	2.3^{b}	2.4^{b}	2.2^{ab}	0.06	0.02
Apparent digestibility, %						
DM	56.8	59.6	58.8	58.8	1.8	0.74
OM	60.1^{a}	65.6^{b}	65.2^{b}	63.4^{ab}	1.1	0.02
CP	58.5^{a}	64.4^{b}	62.6^{ab}	60.5^{ab}	1.6	0.05
NDF	49.7	57.6	53.2	48.6	3.1	0.24
ADF	41.6	35.9	39.7	34.7	3.5	0.32

[a,b] Means in 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; T1: 74; T2: 76.1; T3: 80.6; T4: 84.3% TDN; SEM, standard error of the mean; [1]1 kg DOM, 3.8 Mcal ME/kg (Kearl 1982).

Table 4. Influence of TDN levels on nitrogen balance, excretion of urinary derivatives and microbial nitrogen supply in swamp buffaloes

Items	Treatments,%TDN				SEM	P-value
	T1	T2	T3	T4		
N balance, g/d						
Total N intake	67.4	62.5	62.0	57.0	3.5	0.29
N excretion, g/d						
Fecal N	34.3	29.2	26.6	29.7	8.0	0.33
Urinary N	11.5[a]	17.5[b]	10.8[a]	14.9[a]	2.3	0.05
Total N excretion						
Absorbed N	33.0	33.4	35.4	27.3	4.8	0.68
Retained N	21.5	15.8	24.5	12.4	4.9	0.35
Purine derivatives, mmol/d						
PD excretion	77.8[a]	98.5[b]	96.5[b]	82.9[a]	3.7	0.01
PD absorption	54.3[a]	81.4[c]	71.9[ab]	64.7[ab]	4.5	0.02
MNS, g/d	39.5[a]	59.2[c]	52.3[ab]	47.1[ab]	3.3	0.02
EMNS, g/kg OMDR[1]	12.4	17.8	14.1	14.1	1.5	0.18

[a,b,c]Means in the same row with different superscripts differ (P<0.05); [1]Efficiency of microbial N synthesis (EMNS, g/kg of OM digested in the rumen (OMDR), [(MCP (g/d) × 1000)/DOMR (g)], assuming that rumen digestion, 65% of digestion in total tract; MNS: microbial nitrogen supplies; T1: 74; T2: 76.1; T3: 80.6; T4: 84.3% TDN; SEM, standard error of the mean.

80.6 and 80.6 to 84.3% TND, respectively, except for total volatile fatty acid, acetic acid (C_2), acetic acid to propionic ratio (C_2/C_3) that were not affected by treatments.

Ruminal pH ranged from 6.3 to 6.4, according to Wanapat and Pimpa (1999), who suggested that the optimum level of pH in the rumen should be 6.5–7.0 when fed on low-quality roughages especially rice straw. Generally, rate and extent of volatile fatty acids production were influenced by carbohydrate fraction and degradability of carbohydrate (McDonald *et al.* 1995). However, Bach *et al*. (1999) found that proportion of acetate increased with increased fiber intake while Zebeli *et al*. (2008) found that elevating non-structural carbohydrate intake decreased ruminal acetate proportion. However, propionic acid and butyric acid both increased at the same time due to the high proportion of tallow and molasses. Nonetheless, it is noteworthy that greater butyrate concentration in rumen fluid was associated with greater feed efficiency of beef cattle (Guan *et al.* 2008) while Sutoh *et al.* (1996) reported that feeding sucrose as energy increased the concentration of propionate as well as butyrate in the rumen fluid. Moreover, high-concentrate diets tend to ferment toward propionate, and low rumen pH also results in greater ruminal propionate molar proportions (Calsamiglia *et al*. 2008). The highest proportion of propionic acid and butyric acid on high TDN diet indicated a better use of the TDN for microorganisms producing propionic acid in the rumen.

The effects of TDN levels on nitrogen balance, excretion of urinary derivatives and microbial nitrogen supply in swamp buffalo fed on rice straw based diet are presented in Table 4. Nitrogen urinary and purine derivatives (PD) excretion were significantly different between the 76.1 and 76.1 to 80.6%TDN, respectively, while PD absorption and efficiency of microbial N synthesis were significant (P<0.05) improvements with the use of 76.1%TDN. These were similar to Liu *et al*. (2005) who reported that increasing energy of concentrate mixtures supplementation level significantly increased urinary N excretion and under this study, cassava chip was been used as a readily fermentable carbohydrate in ruminant rations successfully (Wanapat 2009). Therefore, energy in concentrate mixtures supplementation at 76.1 and 80.6% increased allantoin excretion, allantoin absorption and microbial N supplies.

Based on this study, it could be concluded that using 76.1 to 80.6%TDN, in the concentrate mixtures as supplements to response improved DMI, nutrient OM intake, estimated ME, OM, and CP, digestibility, without negatively affecting on rumen fermentation and hence, improving rumen fermentation efficiency at 76.1 to 80.6% TDN were recommended and were most suitable for feeding with rice straw as a roughage for swamp buffaloes.

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