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Effects of Amount of Concentrate Supplement on Forage Intake, Diet Digestibility and Live Weight Gain in Yellow Cattle in Vietnam

Nguyen Xuan Ba*, Nguyen Huu Van, Le Duc Ngoan, Clare M. Leddin[1] and Peter T. Doyle[1]
Faculty of Animal Sciences, Hue University of Agriculture and Forestry, 102 Phung Hung, Hue City, Vietnam

ABSTRACT : Two experiments were conducted in central Vietnam to test the hypothesis that supplementation with a concentrate, comprising rice bran (45% fresh basis), maize (49%), fish meal (3%), urea (2%) and salt (1%), up to 2% of live weight (LW)/d (dry matter (DM) basis) would linearly increase digestible organic matter intake and LW gain of yellow cattle. In both experiments, there were five treatments, namely a basal diet of fresh grass fed at 1.25% of LW (experiment 1, elephant grass, *Pennisetum purpureum*; experiment 2, native grass) and rice straw (*Oryza sativa*) fed *ad libitum* or this diet supplemented with concentrate at about 0.3, 0.7, 1.3 or 2.0% LW. There were 4 male growing cattle per treatment in experiment 1 and 3 in experiment 2. Diets were fed for 44 (experiment 1) or 49 (experiment 2) days, with feed intake recorded daily, LW measured about weekly and digestibility measurements made over 7 days commencing on day 24 (experiment 1) or day 10 (experiment 2). The elephant grass and native grass had neutral detergent fibre (NDF) concentrations of 82 and 73% DM, and nitrogen concentrations of 1.3 and 1.8% DM, respectively. The rice straw used had a NDF concentration of 79-84% DM and nitrogen concentration of 0.8% DM. The concentrate had NDF and nitrogen concentrations of 33 and 2.8% DM. In both experiments, DM intake increased ($p<0.001$) linearly as the amount of concentrate consumed increased. Rice straw intake declined ($p<0.001$) (experiment 1: 1.24 to 0.48 kg DM/d; experiment 2: 0.95 to 0.50 kg DM/d) as concentrate intake increased. Grass intake was not significantly affected by concentrate intake in either experiment. The lowest amount of concentrate supplement increased forage intake, after which substitution rate increased as the amount of concentrate consumed increased. However, substitution rates at the highest amount of concentrate consumed were modest at 0.3 to 0.5 kg DM reduction in forage intake/kg DM supplement consumed. In both experiments, digestible organic matter intake increased linearly ($p<0.001$) (experiment 1: 1.16 to 2.38 kg/d; experiment 2: 1.30 to 2.49 kg/d) as the amount of supplement consumed increased, as did LW gain (experiment 1: 0.15 to 0.81 kg/d; experiment 2: 0.15 to 0.77 kg/d). This was associated with significant ($p<0.01$) linear increases in organic matter intake and apparent organic matter digestibility. Neutral detergent fibre digestibility declined as concentrate intake increased, but the effect was not significant ($p = 0.051$) in experiment 2. These results are discussed in relation to existing literature and potential to improve the profitability of cattle fattening in central Vietnam. (**Key Words :** Concentrate, Forage Intake, Growth Rate, Yellow Cattle, Vietnam)

INTRODUCTION

Most cattle in the low land farming systems in central Vietnam are allowed to graze native grasses during the day and are fed rice straw (*Oryza sativa*) at night throughout the year (Ba et al., 2005). In some communes, where animals are kept in confinement, the basal diet includes cut-and-carry grass, and there is increasing use of sown species, such as elephant grass (*Pennisetum purpureum*). Rice bran, maize and/or cassava powder supplements are fed to fatten cattle in these confinement systems, but the amount offered is usually about 1 kg/d irrespective of the age, weight or condition of the animals and these feeds are often not mixed. In general, rice straws are low in metabolisable energy and protein (Doyle et al., 1986), while the dry matter digestibility of tropical grasses varies between 30 and 70% (Wilson and Minson, 1980) and declines during growth, although the rate of decline varies with species (Norton, 1982). These basal diets and the limited amount of supplement fed lead to low rates of growth.

Supplementation with greater amounts of energy-rich feeds with a source of protein could reduce the time taken to finish cattle for market and increase profitability. Numerous reports in the literature indicate substantial increases in live weight (LW) gain by supplementing cattle consuming low digestibility forages with energy and protein

* Corresponding Author: Nguyen Xuan Ba. Tel: +84-54-525-439, Fax: +84-54-524-923, E-mail: bao.nguyenxuan@gmail.com
[1] Future Farming Systems Research Division, Department of Primary Industries, Kyabram Centre, 120 Cooma Road, Kyabram, Victoria, 3620, Australia.
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supplements (Hennessy and Murrison, 1982; Lee et al., 1987; Hennessy et al., 1995). Hennessy and Murrison (1982) reported that LW change was a function of digestible organic matter intake in steers fed increasing amounts of molasses or cottonseed meal. In central Vietnam, as the amount of concentrate fed increases, it is likely that the energy-rich feeds available, rice bran, maize and cassava powder, will need to be mixed and sources of protein added to optimise responses to supplementation. For example, Ba et al. (2008) reported that increasing the amount of a cassava powder and urea supplement increased LW gain of Laisind cattle, but there were limits to how much of this supplement cattle would consume, adverse effects on neutral detergent fibre (NDF) digestibility, and high substitution rates of cassava powder for forage. Cassava powder is rich in highly digestible starch, and negative associative effects on forage digestion when fed in significant quantities can be expected with this type of supplement (Mould et al., 1983; Huhtanen, 1991).

The hypothesis tested in the experiments reported here was that supplementation with a concentrate comprised of rice bran (45% fresh basis), maize (49%), fish meal (3%), urea (2%) and salt (1%) up to 2% of LW/d would result in linear increases in digestible organic matter intake and LW gain of yellow cattle.

MATERIALS AND METHODS

Experimental designs and timetable

The experiments were conducted at Hue University of Agriculture and Forestry (HUAF) farm in Thua Thien Hue Province (16°00' to 16°48' N, 107°48' to 108°12' E) and had 5 treatments. In both experiments the treatments were:

T1: basal diet (control) of fresh grass at 1.25% of LW (dry matter (DM) basis) fed between 0730 and 1800 h and rice straw at 25 to 50% above the previous days intake from 1830 to 0700 h.

T2: T1 plus 0.33% of LW (DM basis) of concentrate
T3: T1 plus 0.66% of LW (DM basis) of concentrate
T4: T1 plus 1.32% of LW (DM basis) of concentrate
T5: T1 plus 1.98% of LW (DM basis) of concentrate

Elephant grass was used in experiment 1, while in experiment 2 it was native grass. There were 4 animals per treatment in experiment 1, and 3 in experiment 2.

The concentrate ingredients were well mixed to ensure uniform consistency and nutritive characteristics and it was formulated based on book values to have a crude protein concentration of about 15% DM. The experimental treatments commenced on 25 August 2006 (day 1) and continued to day 44 in experiment 1, while in experiment 2 treatments commenced on 30 October 2006 (day 1) and continued to day 49. The amounts of concentrate and fresh grass offered to each animal were adjusted weekly.

For T2 and T3, the supplement was fed in 2 equal amounts at 0715 h and 1630 h, and the cattle generally consumed the entire supplement within 15 min. For T4 and T5, the supplement was fed in 3 equal amounts at 0715 h, 1300 h, and 1630 h, and again the cattle consumed most of what was offered in 15 min. When residues occurred, they were only collected in the morning.

Each animal had free access to a mineral block and water. The hard mineral block was comprised primarily of salt, but contained 3% urea, 5% cottonseed meal, 5% molasses and a mineral premix. As the amount of block consumed daily was small, no account was taken of the intake of organic matter or nitrogen from this source. Water was freely available to each animal from a drinker within each pen.

Elephant grass was produced on the HUAF farm on a loam soil and was harvested after 40 to 45 days re-growth in the late afternoon, transported to the animal house, and in the morning it was mechanically chopped to 5 to 10 cm lengths prior to feeding. Half of each animal's allocation was fed at 0730 h, and the remainder was offered at about 1315 h. The native grass (experiment 2) was harvested daily from along the banks of the Huong river. It was also chopped prior to feeding.

The rice straw used was mechanically chopped to 15 to 20 cm lengths prior to feeding. In experiments 1 and 2, respectively, rice straw in the T1 to T3 treatments was offered at 25-35% or 35-50% above the previous day's intake at 1830 h and residues were collected at 0700 h. For T4 and T5 in both experiments, the average amount of rice straw offered was over 50% in excess of intake on the previous day.

The amounts of all feeds offered and residues were recorded daily. Sub-samples of each feed and of residues, when they occurred, were taken every day for DM determination.

Animals and management

Twenty growing entire male yellow cattle about 12 to 15 months of age and weighing 116±12.3 kg were used in experiment 1. The animals were blocked on the basis of LW into groups of 5, and allocated at random within each group to treatments. The cattle were adapted to the housing in individual stalls and feeding management for 14 days, during which time they were fed the basal forage diet plus 1.0 kg DM of the concentrate supplement. In experiment 2, 15 growing entire male yellow cattle about 14 to 17 months of age and weighing 142±15.7 kg were used. Only 15 animals (three per treatment) were used in experiment 2 as it was not possible to purchase 20 uniform animals at the time. They were adapted to the basal diet and allocated to treatments as described above. All animals were treated for internal parasites and liver fluke with Bioxinil (Bio Pharmachemie, Ho Chi Minh) and vaccinated for pasteurellosis with P15 vaccine (NaVetCo, Ho Chi Minh City) prior to the experiments. Cattle were weighed between 0630 and 0730 h before feeding on 2 or 3 consecutive days at the start and end of the experiments, and at least once each week including at the start and end of the digestibility periods.

Digestibility measurements

During digestibility periods (days 24 to 30 in experiment 1; days 10 to 16 in experiment 2), sub-samples of feed and feed residues were collected daily, dried and stored for subsequent analysis. Faeces were quantitatively collected by hand immediately as or after an animal defaecated during these periods. The faeces collected each day were thoroughly mixed, and sub-samples of about 5% taken for DM determination and for storage at -20°C. At the end of collection periods, faecal samples from each animal were mixed and dried at 60°C prior to chemical analysis. All samples were ground through a 1 mm screen in a mill (Retsche, Germany).

Analytical procedures

Samples of feeds and faeces were analysed for DM, nitrogen (N), ether extract, and ash according to AOAC (1990). Crude protein concentration was calculated as N× 6.25. Gross energies of feeds and faeces were determined by bomb calorimetry (Bomb Calorimeter 6300, Parr Instrument Company). Neutral detergent fibre was determined as described by Van Soest et al. (1991).

Calculations

Maximum and minimum temperatures, relative humidity and rainfall data were obtained from a weather station at the University farm. The temperature-humidity index (THI) was calculated as:

$$\text{THI} = td-(0.55-0.55\text{RH})(td-58)$$

Where td is the dry bulb temperature in °F and RH is relative humidity expressed as a decimal (National Oceanic and Atmospheric Administration, 1976).

Live weight gain was estimated using regression analysis of weights measured through an experiment.

Substitution of supplement for forage (kg DM reduction in intake of elephant grass plus rice straw (FI)/kg DM concentrate consumed) was calculated for each animal receiving the concentrate as:

$$\text{Substitution rate} = \frac{(\text{FI in un-supplemented treatment} - \text{FI in supplement treatment})}{\text{Concentrate intake in supplement treatment}}$$

As the bulls were grouped on LW before allocation to treatments, the forage intake without supplement use was from the control animal within each group.

Apparent digestibility of DM, organic matter, energy and crude protein and digestibility of NDF were calculated as intake minus faecal output divided by intake and converted to a percentage.

Statistical analysis

In both experiments, effects of dietary treatments on feed and nutrient intake and digestibility, final LW and LW change were tested using analysis of variance in a completely randomised design using GenStat 9 (Lawes Agricultural Trust, Rothamstead, UK). Where the effects of dietary treatments were significant, relationships between the amount of concentrate actually consumed and intakes of feed or feed constituents, digestibility or LW change were examined. While a polynomial contrast of order 2 (quadratic) was fitted to model the relationship between the measured variables and the amount of concentrate consumed, only linear relationships were significant except for substitution rate in experiment 1. Presented data were for the whole of an experiment except for that specifically associated with digestibility measurements. Residual diagnostics performed after each analysis showed the models fitted the data well.

Economic analysis

This was conducted for a confinement feeding system where a young bull was grown from 120 to 170 kg using a basal diet of elephant grass and rice straw. The benefits of feeding the formulated concentrate at 1 or 2% LW were evaluated. Purchase and sale prices for the bull were based on market information, where the average price was VND 20,000/kg LW. Prices can be 20% higher than this when supply is limited or around the TET festival.

The costs of growing the grass, including labour, were VND 200/kg fresh. The household produced its own maize and rice bran, and they were valued at VND 2,400/kg fresh, the price the farmer would receive if they sold these to a feed merchant. Purchase prices of maize and rice bran from feed merchants were VND 3,000/kg fresh. Rice straw was valued at VND 100/kg fresh to reflect costs in collection and cartage. Commercial prices were used for fish meal (VND 8,000/kg fresh), urea (VND 6,000/kg) and salt (VND 500/kg).

Labour for harvesting grass, mixing the concentrate, feeding and animal husbandry was valued at two levels, VND 2,000 or 5,000/d, to reflect use of secondary labour

Table 1. Nutritive characteristics of the grasses, rice straw and concentrates used in experiments 1 and 2

Nutritive characteristics	Experiment 1			Experiment 2		
	Elephant grass	Rice straw	Concentrate	Native grass	Rice straw	Concentrate
Dry matter (%)	20.6	85.2	84.0	20.0	85.8	84.4
Organic matter (% DM)	94.6	90.6	93.3	88.8	88.5	93.9
Neutral detergent fibre (% DM)	82.2	84.4	33.3	72.7	78.9	33.4
Crude protein (% DM)	8.1	5.2	17.2	11.1	5.2	17.4
Ether extract (% DM)	2.3	1.5	7.4	1.5	1.4	7.5
Gross energy (MJ/kg DM)	18.4	17.8	17.8	17.7	17.8	17.9

(children under 16 years and adults over 60 years of age) or the opportunity cost if primary labour was employed off farm, respectively. It was assumed the cattle house required no repairs and maintenance and depreciation was ignored.

RESULTS

Environmental conditions and feeds

The average daily temperature was 26.8°C (range 23.7 to 29.7°C) in experiment 1 and 24.9°C (range 21.6 to 27.3°C) in experiment 2. The average relative humidity in experiments 1 and 2 was 86% (74 to 97%) and 89% (83 to 99%), respectively. The calculated THI was on average 78.5, with 13 days where the index was 80 or above in experiment 1 and 75.6, with no days where the index was 80 or above in experiment 2.

The forages were all high in NDF, and the elephant grass and native grass had reasonable protein concentrations (Table 1). The concentrate supplement contained 17% crude protein which was higher than estimated from book values of ingredient composition.

Feed intake, digestibility and live weight gain

The amount of concentrate consumed increased from T1 to T5 in both experiments (Tables 2 and 3). In both experiments, total DM intake (TDMI; kg DM/d) increased

Table 2. Organic matter, neutral detergent fibre (NDF), crude protein and gross energy intake and digestibility of male yellow cattle fed a basal diet of elephant grass and rice straw supplemented with concentrates comprised of rice bran, maize, fish meal, urea and salt (experiment 1)

	T1	T2	T3	T4	T5	SED	Relationship	p
Concentrate intake (kg DM/d)[1]	0.00	0.39	0.80	1.57	2.45	-	-	-
Organic matter intake (kg/d)	2.28	2.78	3.18	3.33	3.91	0.316	Y = 2.44+0.63 CI	<0.001
Organic matter digestibility (%)	51.2	53.3	54.7	55.3	60.5	3.30	Y = 51.3+3.6 CI	0.003
Digestible OM intake (kg/d)	1.16	1.49	1.74	1.86	2.38	0.256	Y = 1.23+0.47 CI	<0.001
NDF intake (kg/d)	2.04	2.30	2.44	2.17	2.25	0.253	-	NS
NDF digestibility (%)	56.2	54.4	51.6	45.2	46.4	4.36	Y = 55.1+4.2 CI	0.015
Crude protein intake (kg/d)	0.17	0.24	0.32	0.41	0.55	0.031	Y = 0.18+0.15 CI	<0.001
Crude protein digestibility (%)	44.0	47.9	51.8	57.0	64.2	3.81	Y = 44.4+8.3 CI	<0.001
Gross energy intake (MJ/d)	44.6	54.2	61.7	64.1	75.1	6.13	Y = 47.7+11.8 CI	<0.001
Gross energy digestibility (%)	45.9	48.2	49.9	49.6	55.1	3.80	Y = 46.1+3.5 CI	0.011
Digestible energy intake (MJ/d)	20.4	26.2	30.9	32.3	41.7	5.00	Y = 21.7+8.3 CI	<0.001

[1] Concentrate intake during the 7 day digestibility period.

Table 3. Organic matter, neutral detergent fibre (NDF), crude protein and gross energy intake and digestibility of male yellow cattle fed a basal diet of native grass and rice straw supplemented with concentrates comprised of rice bran, maize, fish meal, urea and salt (experiment 2)

	T1	T2	T3	T4	T5	SED	Relationship	p
Concentrate intake (kg DM/d)[1]	0.00	0.45	0.93	1.80	2.36	-	-	-
Organic matter intake (kg/d)	2.35	3.19	3.21	3.65	4.02	0.365	Y = 2.57+0.65 CI	<0.001
Organic matter digestibility (%)	55.1	55.3	55.0	60.6	61.9	2.41	Y = 54.0+3.3 CI	<0.001
Digestible OM intake (kg/d)	1.30	1.78	1.77	2.22	2.49	0.259	Y = 1.37+0.49 CI	<0.001
NDF intake (kg/d)	1.98	2.50	2.28	2.23	2.30	0.248	-	0.382
NDF digestibility (%)	58.0	54.9	54.8	49.8	50.7	4.43	-	0.051
Crude protein intake (kg/d)	0.25	0.35	0.40	0.53	0.60	0.052	Y = 0.26+0.15 CI	<0.001
Crude protein digestibility (%)	48.4	51.3	50.7	59.8	61.8	3.61	Y = 47.9+5.9 CI	<0.001
Gross energy intake (MJ/d)	47.0	63.5	63.4	71.3	78.3	7.16	Y = 51.3+12.1 CI	<0.001
Gross energy digestibility (%)	49.7	50.2	49.3	55.5	57.5	2.69	Y = 48.5+3.6 CI	<0.036
Digestible energy intake (MJ/d)	23.4	32.1	31.2	39.7	45.0	4.83	Y = 24.6+8.8 CI	<0.010

[1] Concentrate intake during the 7 day digestibility period.

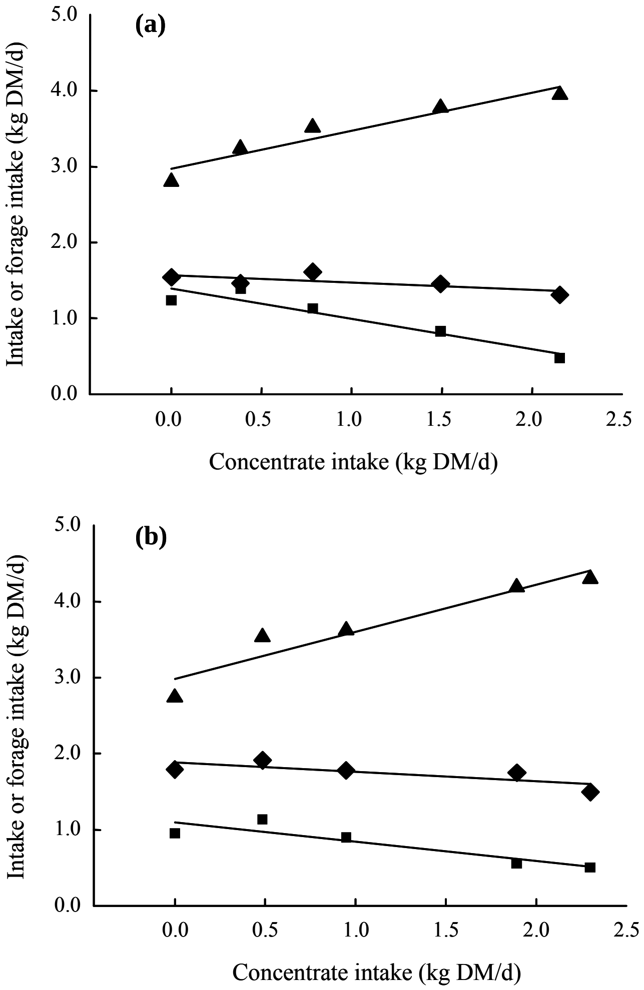

Figure 1. Effects of amount of concentrate consumed on (a) total dry matter intake (▲), elephant grass (◆) and rice straw (■) intakes in experiment 1, and on (b) total dry matter intake (▲), native grass (◆) and rice straw (■) intakes in experiment 2. Values are average intakes measured across the entire experimental period.

linearly as the amount of concentrate consumed (CI; kg DM/d) increased (Figure 1), with the following equations describing the relationships:

Experiment 1:
TDMI = 2.94 (±0.127)+0.53 (±0.103) CI
(R^2 = 0.599; p<0.001)

Experiment 2:
TDMI = 2.94 (±0.164)+0.66(±0.116) CI
(R^2 = 0.713; p<0.001)

Rice straw intake (RSI; kg DM/d) declined linearly with increasing intake of concentrate (CI; kg DM/d) in both experiments (Figure 1), the relationships being:

Experiment 1:
RSI = 1.38 (±0.077)-0.38 (±0.062) CI
(R^2 = 0.684; p<0.01)

Experiment 2:
RSI = 1.09 (±0.095)-0.25(±0.067) CI
(R^2 = 0.514; p<0.01)

The intakes of elephant grass (p = 0.273) or native grass (p = 0.218) were not significantly affected by concentrate intake, although there were some grass refusals at the highest concentrate intake. The lowest amount of concentrate supplement increased forage intake (experiment 1-0.20 kg DM increase in forage intake/kg DM concentrate consumed; experiment 2-0.64 kg DM increase in forage intake/kg DM concentrate consumed), after which substitution rates were positive and tended to increase with concentrate intake (experiment 1: T3 to T5 rates were 0.05, 0.32 and 0.48 kg DM reduction in forage intake/kg DM concentrate consumed; experiment 2: T3 to T5 rates were 0.06, 0.24 and 0.34 kg DM reduction in forage intake/kg DM concentrate consumed). The relationships between substitution rate (SR) and concentrate intake averaged over the whole of each experiment are described by:

Experiment 1:
SR = -0.59 (±0.141)+1.06(±0.261) CI-0.27(±0.098) CI^2
(R^2 = 0.796; p<0.001)

Experiment 2:
SR = -0.61(±0.265)+0.43(±0.166) CI
(R^2 = 0.400; p = 0.027)

In both experiments, organic matter, digestible organic matter, crude protein, gross energy and digestible energy intakes increased linearly as the amount of concentrate consumed increased (experiment 1: Table 2; experiment 2: Table 3). Apparent organic matter, apparent crude protein and gross energy digestibilities increased linearly with amount of supplement consumed in both experiments, and NDF digestibility declined in experiment 1 and there was a non significant trend in this direction in experiment 2.

Live weight gain (LWG, kg/d) increased linearly as the amount of concentrate consumed increased in both experiments (Figure 2), with the relationships being:

Experiment 1:
LWG = 0.19 (±0.026)+0.29(±0.021) CI
(R^2 = 0.916; p<0.001)

Experiment 2:
LWG = 0.17(±0.039)+0.27(±0.027) CI
(R^2 = 0.878; p<0.001)

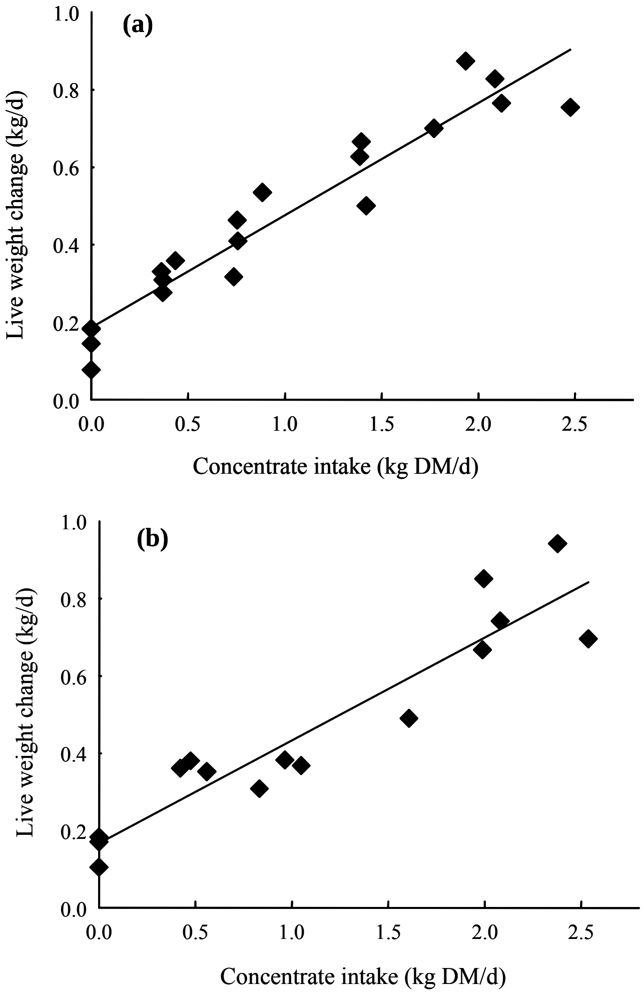

Figure 2. Effects of amount of concentrate consumed on live weight gain of yellow cattle fed (a) a basal diet of elephant grass and rice straw (experiment 1) or (b) a basal diet of native grass and rice straw (experiment 2) measured over the whole experiment. Values are for individual bulls, 20 in experiment 1 and 15 in experiment 2.

DISCUSSION

Present results support the hypothesis that digestible organic matter intake and LW gain would increase linearly as the amount of a formulated concentrate based on rice bran and maize consumed increased up to 2% LW. There was a significant linear relationship between digestible organic matter intake (DOMI) and LW gain across the two experiments, namely:

LW gain = 0.53(±0.054) DOMI-0.50(±0.100)
(R^2 = 0.924; p<0.001; n = 10)

This result is consistent with previously published reports where supplements have been fed to provide energy and/or protein to cattle consuming low quality forages (Hennessy and Murrison, 1982; Lee et al., 1987; Hennessy et al., 1995).

The basal diet of cattle in central Vietnam is generally rice straw supplemented with green forage from grazed native grass (Ba et al., 2005). In cattle finishing systems in the lowlands, there is a shift to confinement systems, with sown grasses being used as supplements to rice straw. The effect of adding green forage supplements, like elephant grass, to straw diets is to increase metabolisable energy intake (Elliott and McMeniman, 1987). In the experiments reported here, the amount of grass fed was restricted to 1.25% LW to reflect limited availability of such feeds, and there was no apparent difference between the elephant and native grasses. Both grasses contained reasonable concentrations of crude protein and the ratio of digestible organic matter to crude protein in the basal diets was 6.8 (experiment 1) and 5.2 (experiment 2). Hogan (1982) concluded that microbial activity in ruminants consuming forage diets was only likely to be limited by ammonia when the digestible organic matter to crude protein ratio was 10:1 or more. Hence, forage intake on the basal diets was reasonable and supported growth rates of over 0.1 kg/d.

The apparent increase in forage intake at the lowest amount of supplement consumed was likely to be due to the supply of nutrients that were limiting digestion in the rumen or tissue metabolism when the forages were fed alone (see Doyle, 1987). These positive effects of small amounts of supplement on intake of low and medium quality forages have been reported elsewhere (Cohen, 1974; Ernst et al., 1975; Lee et al., 1987), although such effects are not always found (Hennessy and Murrison, 1982; Hennessy et al., 1983; Smith and Warren, 1986). The feeding management used, restricted access to grass during the day and *ad libitum* feeding of straw at night, may have constrained the complementary effect of low amounts of the supplement on forage intake. However, as the amount of supplement consumed increases, even with formulated concentrates, substitution invariably occurs (Doyle, 1987). Substitution rates of concentrates for forage in ruminants grazing pastures or fed *ad libitum* on conserved forages generally range between 0 and 1.0 kg DM/kg DM (Stockdale et al., 1997; Stockdale, 2000; Heard et al., 2004). In the present study, estimated substitution rates were modest (0.3 to 0.5 kg DM reduction in forage intake/kg DM supplement consumed) even at the highest amounts of supplement consumed. The restricted feeding of grass would have contributed to this result, but increasing the amount of formulated concentrate fed also removed energy and possibly other nutrient limitations to production.

Doyle (1987) concluded that substitution effects are mediated by many complex factors operating within the rumen and animal's tissues. The concentrate supplement was formulated to provide readily digestible energy from locally available concentrates, but also protein and non-protein N. In ruminants fed low quality forages, providing protein or non-protein N to the rumen organisms (Leibholz and Kellaway, 1984; Egan and Doyle, 1985) or additional amino acids at the tissue level (Egan, 1965; Kempton et al., 1979) can increase forage intake, and possibly also moderate substitution effects. Crude protein intake and digestibility both increased linearly as the amount of concentrate consumed increased, but the ratios of digestible organic matter to crude protein on the supplemented diets was between 4.2 and 6.2. Since ammonia supply in the rumen was unlikely to be limiting microbial activity (Hogan, 1982), the supplement may have alleviated limitations imposed by amino acid supply to the tissues. The increase in apparent digestibility with increased crude protein intake has been reported previously by Hunter and Siebert (1980) and Hennessy and Murrison (1982). Any effects of increased crude protein intake in moderating substitution were likely to be due to increased amino acid supply to the tissues, and less protein, and particularly urea, could have been used in the formulated supplement.

The formulated concentrate had only modest effects on fibre digestion in the rumen compared with earlier research, where a highly digestible starch supplement, cassava powder, depressed NDF digestibility from 62 to 41% as the amount consumed increased (Ba et al., 2008). Wanapat and Khampa (2007) reported significant declines in the cellulolytic bacterial population when cassava chip supplements were fed to cattle, and presumably these effects were smaller with the formulated concentrate in the experiments reported here. Cereal grains vary in their level of starch and starch degradation characteristics and have been ranked in order of rates of *in vitro* fermentation: wheat>triticale>oats>barley>maize>rice and sorghum (Opatpatanakit et al., 1994). Wheat and barley inhibit NDF digestion *in vitro* to a greater extent than maize (Opatpatanakit et al., 1995), and it would appear the slower degradation rates of starch in the maize and rice bran may have limited negative associative effects of the formulated concentrate on NDF digestibility. However, it is also important that under the feeding management imposed in the current experiments that nearly all of the substitution was associated with reductions in straw intake. There is evidence that the digestibility of NDF in mature forages may be depressed more than that of fresh herbages when the rumen environment is altered by feeding concentrates (Mould et al., 1983; Huhtanen, 1991) and Dixon and Stockdale (1999) have suggested that reduced NDF digestion is a primary cause of substitution.

Economic analysis based on the data from experiment 1 (Table 4) indicates the profitability of finishing cattle in central Vietnam can be substantially increased by appropriate use of well formulated concentrates. The benefits accrued from a reduced time to achieve the target weight and increased partitioning of energy from the concentrate to LW gain. The implications of labour costs on profit were significant (Table 4). In many circumstances in developing countries labour costs are not included in such analyses. It is also important that labour efficiencies would be gained where more than one animal is finished at one time. If the household needed to purchase all of the concentrate used, profit would decline when the concentrate was fed at 2% LW by VND 90,000 for each animal finished. This indicates that the resources available within a household have a marked impact on the economics of finishing cattle in these small holder systems and may determine the number of cattle a farmer is prepared to finish and the time of year when they will finish animals. Cash flow and access to credit are primary constraints to increased cattle production in rural households underscoring the need to fully utilise feed resources available within the farm. The response relationships generated in this research

Table 4. Economic evaluation of feeding a concentrate supplement comprised of rice bran, maize, fish meal, urea, and salt at 1 or 2% LW for a LW gain of 50 kg (120 to 150 kg LW) in yellow cattle

Labour cost / Concentrate	Secondary labour (VND 2,000/d)			Primary labour (VND 5,000/d)	
	0	1% LW	2% LW	1% LW	2% LW
Sale price	3.40	3.40	3.40	3.40	3.40
Purchase price	2.40	2.40	2.40	2.40	2.40
Time taken to 170 kg LW	278	88	52	88	52
Labour costs	0.56	0.18	0.10	0.44	0.26
Supplement fed (kg fresh)	0	136	161	136	161
Supplement costs (VND)	0	0.36	0.43	0.36	0.43
Grass fed (kg fresh)	2431	763	453	763	453
Grass costs (VND)	0.49	0.15	0.09	0.15	0.09
Straw fed (kg fresh)	482	137	57	137	57
Straw costs (VND)	0.05	0.01	0.00	0.01	0.00
Total feed costs (VND)	0.53	0.53	0.52	0.53	0.52
Revenue-costs (VND)	-0.09	0.30	0.37	0.03	0.22

All prices and costs are in Vietnamese dong (VND×10^6).
Prices and costs are detailed in the methods.

enable extension staff and farmers to design feeding strategies that meet the needs of farmers with different financial positions. Reducing the cost of protein supplements, which are not available within the farm, is likely to impact on the implementation of feeding strategies using formulated concentrates in this region. Hence, further work defining the requirements for protein in the supplement, and how this is affected by the characteristics of forages in the basal diet is warranted.

It is concluded that household income and profit from cattle finishing can be increased through better use of concentrates. Traditional practice involves feeding low amounts of either cassava powder, maize or rice bran once a day. Formulating concentrates based on a mix of these ingredients, feeding increased quantities (up to 2% LW), and more frequent feeding will increase growth rates, reduce the time taken to achieve target live weight and labour inputs and dilute the amount of energy used for maintenance. Factors such as labour and the feed resources available within a household will impact on profit.

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