Productive Performance, Rumen Volatile Fatty Acid Profile and Plasma Metabolites of Concentrate-Supplemented Bach Thao Goats in Vietnam

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Abstract: Twenty-five Bach Thao bucks (7 month old and 20.9±0.3 kg BW) were used to quantify the effect of concentrate supplementation on growth performance, rumen volatile fatty acid profile, digestibility and plasma metabolites. Goats were allocated into five treatment groups of varying levels of concentrate supplementation: Control (*ad libitum* access to elephant grass), 0.6% C (control plus 0.6% of concentrates), 1.2% C (control plus 1.2% of Concentrates), 1.8% C (control plus 1.8% of Concentrates) and 2.4% C (control plus 2.4% of Concentrates) as a percentage of liveweight on a dry matter basis. Growth and feed intake were measured in a 6 week feeding trial period after 3 week of initial adaptation. *In vivo* digestibility was assessed in the 10th week by the total faecal collection method. There were significant increase sin Average Daily Gain (ADG), feed intake and digestibilities of Dry Matter (DM), Organic Matter (OM) and Crude Protein (CP) as dietary concentrate levels increased. However, digestibility of Neutral Detergent Fibre (NDF) was not different between the concentrate-supplemented groups. Pre-feeding ammonia concentration in rumen fluid was not different between treatments but 4 h after feeding, significant differences were detected. The values of ammonia ranged from 100-200 mg L^{-1} at both timesof measurement. Rumen fluid pH values were not different 4 h post-feeding. Volatile fatty acid concentrations of propionate and butyrate increased with increasing levels of concentrates consumed, in contrast to decreased acetate concentration. This study clearly demonstrated that increasing concentrate levels offered to Bach Thao bucks up to 1.8% of live weight on a DM basis resulted inthe greatest improvement in ADG, feed intake and nutrient digestibility, thus, confirming the tested hypothesis that increased level of concentrate supplementation will improve productive performance of goats without an adverse effect on rumen fermentation and nutrient digestibility.

Key words: Bach Thao goats, concentrates, digestibility, ammonia, volatile fatty acids

INTRODUCTION

Concentrates are usedin ruminant livestock feeding to meet the growing demand for meat and other animal productsas the human population increases. The role of concentrates in goat rations is to increase dietary energy density, protein quality, feed efficiency and provide ruminal anion-cation balance between the digesta originating from starch and forage dietary sources. However, excessive concentrate supplementation can also lead to depression of rumen fluid pH which in turn reduces fibre digestibility or causes acidosis. Therefore, there is a need to know the optimal amount of concentrates that smallholder goat farmers can efficiently use for dietary supplementation.

Various studies have investigated the use of concentrates and varying levels of dietary supplementationin goats (Cerrillo *et al.*, 1999; Urge *et al.*, 2004; Haddad, 2005; Cantalapiedra-Hijar *et al.*, 2009). However, these studies utilised feed ingredients that are not locally available and it would not be valid to extrapolate the reported nutrient digestibility and rumen fermentation results to the Vietnamese goat production system. The environmentally harsh mountainous areas of Vietnam are characterised by poor quality feeds. Feed quality and quantitylimits the herd size of goats kept by most smallholder farmers to 5-7 head (Nedjraoui, 2006). The area of free grazing pasture is reducing rapidly and the feed quality does not meet the nutrient requirement of

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goats for a high level ofproduction. Intensive or semi-intensive farms that use concentrate are the most economically efficient (Haddad, 2005). Confinement systems with cultivated or cut and carry native grass and concentrate supplements have been created for cattle production in Vietnam (Ba *et al.*, 2008). Similar studies are needed for goat production to improve the economic efficiency of feed utilisation using local ingredients as sources of concentrates.

The objective of this investigation was to evaluate the effect of varying levels of concentrate supplementation on growth performance, digestibility, rumen volatile fatty acid concentrations and plasma metabolites of Bach Thao goats. This research was also conducted to test the hypothesis that a greater level of concentrate supplementation will result in greater productivity, without any adverse impact on rumen fermentation indices and digestibility.

MATERIALS AND METHODS

Animals and housing: The experiment was conducted at Hue University of Agriculture and Forestry Farm in Thua Thien, Hue Province (16°00'-16°48' Latitude, 107°48'-108°12' Longitude) in Vietnam. Twenty five Bach Thao bucks (initial live weight = 20.3 ± 0.9kg (M$\pm$SD)), approximately 7 month old were used for the experiment. On arrival, they were treated with Hanmectin ($2\,mL^{-1}$ 25 kg BW) for internal and external parasites. They were individually housed in pens (1.5×0.75 m) with separate feeding troughs and unrestricted access tofresh drinking water.

Feeding trial: The experimental animals were given a 3 week adaptation period,after random allocation into five treatment groups (five bucks per treatment) in a completely randomized design and fed for 6 week. The five treatment groups were: control (*ad libitum* access to elephant grass (*Pennisetum purpureum*)), 0.6% C (control plus 0.6% of concentrates), 1.2% C (control plus 1.2% of concentrates), 1.8% C (control plus 1.8% of concentrates) and 2.4% C (control plus 2.4% of concentrates) as a percentage of liveweight on a dry matter basis.

Fresh elephant grass was harvested daily and offered to animals *ad libitum* by filling the trough with grass every 2 h during the day time (from 8:00-20:00 h) and filling the trough at night. The concentrate ration was formulated to contain 16% CP, thoroughly mixed and fed twice daily to the goats before the elephant grass was given with the quantity adjusted weekly to match goat liveweight. The chemical compositions of elephant grass, the concentrate ingredients and the mixed concentrateare presented in Table 1.

Table 1: The proportions of ingredients and nutrient contents of theconcentrates and elephant grass

Ingredient	Mixed concentrates	Elephant grass	Proportion ($g\,kg^{-1}$ DM)
Rice bran	-	-	323.4
Maize	-	-	333.2
Fishmeal	-	-	127.4
Cassava powder	-	-	196.0
Mineralsand Vitamins	-	-	10.0
Salt	-	-	10.0
Nutrient composition (%)			
Dry matter	87.2	17.6	-
Crude protein (DM)	15.7	9.2	-
Organic matter (DM)	91.0	89.4	-
Neutral detergent fibre (DM)	30.9	68.7	-
Acid detergent fibre (DM)	5.8	37.5	-

Feed refusal was weighed and recorded the next day before new feeds were served in the morning. Feed samples and elephant grass refusal were analysed weekly for chemical composition. The live weight of animals was measured weekly to calculate the weight gain and adjust the concentrate supplementation levels. After 6 week of experimentation, nutrient digestibility was measured using the total faecal collection method.

Digestibility trial: The last 7 days of the feeding trialwere used for digestibility evaluation in which feed sub-samples, feed refusals and voided faeces were collected, thoroughly mixed and weighed daily at 0800 h. About 10% of the faeces were collected and stored at -20°C. The frozen faecal samples were thawed, mixed and duplicate sub-samples from each goat were dried at 60°C for 48 h before laboratory analysis.

Blood and rumen fluid sample collection
Blood sample collection: Blood samples were collected via jugular venipuncture from each goatbefore and after the feeding trial. The 2 mL of blood samples from each goat were taken and deposited in plastic tubes containinganticoagulant. Samples were centrifuged to separate the plasma from the serum for biochemical analysis usingan Automatic Biochemical analyser (HIT 717, Hitachi, Japan). The parameters measured includedm Plasma Glutamic Oxaloacetic Transaminase (PGOT), Plasma Glutamic Pyruvic Transaminase (PGPT), glucose, urea, creatinine, protein, albumin and cholesterol.

Rumen fluid sample collection: On the last day of the feeding trial, 50 mL of rumen fluid from each buck was taken using a stomach tube at 0 and 4 h after feeding the concentrates. Thereafter, the rumen fluid was filtered through a muslin cloth to remove coarse particles and stored a -20°C for analysis. On the day of analysis, after thawing, rumen fluid was centrifuged at 22,000 g for 15 min, at 4°C.

Sample analysis: Nitrogen concentration in the feeds and faeces was determined using the Kjeltec 8200 (Foss,

Sweden) following the Kjeldahl method (AOAC 984.13). Neutral Detergent Fibre (NDF) was analysed following the method of Van-Soest *et al.* (1991) and Acid Detergent Fibre (ADF) was analysed following the protocol of AOAC (1990) (AOAC 973.18), both using the Fibertec 1020 (Foss, Sweden). Ether Extract (EE) was determined using the Soxtec 2050 (Foss, Sweden) (AOAC 920.39). Rumen fluid samples were analysed for volatile fatty acidsusing the standard Gas Chromatography (GC) Method.

Statistical analysis: Experimental data were analysed using the General Linear Model Procedure of SAS (2009):

$$Y_{ij} = \mu + C_i + \varepsilon_{ij}$$

Where:
μ = The overall mean
C_i = The fixed effect of treatment of concentrate levels (i = Control, 0.6, 1.2, 1.8, 2.4)
ε_{ij} = The random erro

Duncan's multiple range tests were used for mean separation.

RESULTS

Nutrient intake and average daily gain: As the levels of concentrates consumed increased from 0-495 g day^{-1}, there was a decrease ingrass intake from 429-284 g day^{-1} (Table 2). As a result, the total dry matter intake increased significantly (p<0.05) in the control treatment from 429.1-779.2 g day^{-1} in the 2.4% C treatment. There was also an increase (p<0.05) in average daily gain when the proportion of concentrates in the diets increased. The highest ADG value (150 g day^{-1}) was recordedin treatments 1.8 and 2.4% C and the lowest ADG (2.4 g day^{-1} was observed in the control treatment.

Nutrient digestibility: The digestibilities of DM, OM and CP increased significantly (p<0.05) as the level of concentrates in the diets increased (Table 3). The DM digestibility of concentrate-supplemented groups were significantly higher than in the control group in which the 1.8 and 2.4% C treatments resulted in the highest values (80%). OM and DM digestibility values followed the same trend ranging from 63.2-80.2%. Similarly, the greatest CP digestibility was in treatments 1.8 and 2.4% C (76.5 and 76.8%, respectively) and these were significantly higher than in other treatments. The digestibility of NDF in the control treatment was significantly less than in the supplemented groups, except for treatment 1.2% C. However, there was no difference between the concentrate-supplemented treatments.

Rumen fluid ammonia concentration and pH: The pH values before feeding were significantly different between treatments. The 1.2, 1.8 and 2.4% C treatments were higher (p<0.05) than the others (6.5, 6.6 and 6.6, respectively) (Table 4). After 4 h of feeding, there were no significant differences between the treatments, withvalues ranging from 5.9-6.3. Pre-feeding ammonia concentration was not statistically different between treatments,althoughthe values ranged between 103.9 and 148.9 mg L^{-1} However, after 4 h of feeding, the greatest value (229.2 mg L^{-1}) was recorded in treatment 1.2% C which was significantly higher than for the control treatment. There wasno significant difference between the concentrate-supplemented groups.

Rumen volatile fatty acid concentrations: The change in volatile fatty acid concentration followed a similar trend

Table 2: Least squares means (±SD) of feed intake and average daily gainof goats fed varying levels of concentrates

| Parameters | Experimental diet | | | | |
	Control	0.6% C	1.2% C	1.8% C	2.4% C
Grass intake (g)	429.0±62.1[a]	415.7±36.5[a]	376.5±32.5[a]	302.8±58.1[b]	284.1±50.9[b]
Concentrate Intake (g)	-	122.8±9.3	252.5±10.3	378.9±55.1	495.2±36.7
Total DM intake (g)	429.1±62.1[a]	538.5±43.8[b]	629.1±32.3[c]	681.7±105.8[c]	779.2±31.5[d]
ADG (g day^{-1})	2.4±5.3[a]	21.4±17.7[a]	73.8±31.9[b]	150±37.3[c]	150±37.3[c]

ADG = Average Daily Gain; [a-c]Means in the same row with different superscripts are significantly different (p<0.05) according to Duncan's Multiple Range Test

Table 3: Least squares means (±SD) of apparent nutrient digestibility of goats fed varying levels of concentrates

| Digestibility (%) | Experiments | | | | |
	Control	0.6% C	1.2% C	1.8% C	2.4% C
DM	59.4± 7.2[a]	68.2±5.2[b]	72.8±3.4[b]	80.6±3.0[c]	80.8±5.5[c]
OM	63.2±3.9[a]	71.8±4.5[b]	72.0±2.0[b]	78.3±3.2[c]	80.2±2.5[c]
CP	68.6±2.2[a]	70.8±4.9[a]	69.6±4.0[a]	76.5±4.5[b]	76.8±1.8[b]
NDF	64.4±3.1[a]	69.3±4.8[bc]	65.0±3.4[ab]	69.0±2.9[bc]	69.8±1.1[bc]

DM = Dry Matter, OM = Organic Matter, CP = Crude Protein, NDF = Neutral Detergent Fibre; [a-c]Means in the same row with different superscripts are significantly different (p<0.05) according to Duncan's Multiple Range test

Table 4: Ammonia concentration and pH value of rumen fluid before and after 4 hours of feeding (Least squares mean±SD)

Parameters	Experimental diet				
	Control	0.6% C	1.2% C	1.8% C	2.4% C
pH before feeding	6.1 ± 0.3^a	6.0 ± 0.1^a	6.5 ± 0.1^b	6.6 ± 0.1^b	6.6 ± 0.1^b
pH after feeding	6.0 ± 0.4	5.9 ± 0.2	6.3 ± 0.1	5.9 ± 0.3	6.2 ± 0.3
Ammonia before feeding (mg L^{-1})	103.9 ± 18.5	148.9 ± 52.6	139.2 ± 20.7	106.5 ± 72.3	125.8 ± 54.8
Ammonia after 4h of feeding (mg L^{-1})	117.0 ± 33^a	198.0 ± 62.1^{ab}	229.2 ± 56.2^b	146.1 ± 89.8^{ab}	152.8 ± 63.4^{ab}

Table 5: VFA profile of rumen fluid before and 4 h after feeding

Parameters	Control	0.6% C	1.2% C	1.8% C	2.4% C
Before feeding					
Acetate	76.0 ± 2.4^a	74.8 ± 3.2^a	63.0 ± 5.2^b	61.2 ± 4.6^b	59.1 ± 9.1^b
Propionate	18.2 ± 1.6^a	16.8 ± 3.4^a	21.1 ± 2.7^a	23.5 ± 5.6^{ab}	28.7 ± 8.6^b
Butyrate	5.7 ± 2^a	8.4 ± 2.2^a	15.8 ± 4.4^b	15.4 ± 3.3^b	12.2 ± 1.8^b
The 4h after feeding					
Acetate	72.3 ± 3.2^a	69.8 ± 4.1^a	58.0 ± 5.8^b	50.3 ± 5.2^c	53.2 ± 5.8^{bc}
Propionate	21.1 ± 2.9^a	19.7 ± 3.5^a	26.9 ± 4.6^a	37.1 ± 6.7^b	35.5 ± 7.7^b
Butyrate	6.7 ± 1.4^a	10.5 ± 1.5^b	15.1 ± 2.8^c	12.6 ± 2.0^{bc}	$11.4\pm2.5^{ba\text{-}}$

^{c}Means in the same row with different superscripts are significantly different (p<0.05) according to Duncan's Multiple Range test

Table 6: Plasma metabolites before and after the experimental period

Parameters	Experimental diet					Reference value
	Control	0.6% C	1.2% C	1.8% C	2.4% C	
Glucose BF (mmol L^{-1})	2.2 ± 0.5	2.8 ± 0.4	2.5 ± 0.3	2.7 ± 0.4	2.9 ± 0.4	2.8-4.2
Glucose AF (mmol L^{-1})	2.5 ± 0.4^a	2.7 ± 0.3^{ab}	2.9 ± 0.2^{ab}	3.1 ± 0.5^b	2.9 ± 0.3^{ab}	2.8-4.2
PGOT BF (U L^{-1})	207.8 ± 175.4	129.8 ± 15.9	118.2 ± 16.2	155.2 ± 98.1	194.0 ± 130.5	167-513
PGOT AF (U L^{-1}	124.8 ± 27.6	127.4 ± 57.8	114.0 ± 15.2	119.0 ± 47.4	107.0 ± 23.1	167-513
PGPT BF (U L^{-1}	43.6 ± 11.5	29.2 ± 2.3	25.0 ± 5.3	32.8 ± 10.3	34.8 ± 12.8	6-19
PGPT AF (U L^{-1}	28.6 ± 4.9	32.4 ± 6.4	42.0 ± 23.3	27.2 ± 12.7	25.6 ± 1.7	6-19
Urea BF	5.4 ± 0.5	6.0 ± 0.5	6.2 ± 1.2	7.5 ± 3.5	6.4 ± 2.2	3.6-7.1
Urea AF	5.2 ± 0.5	4.9 ± 0.7	4.9 ± 0.7	4.3 ± 0.9	5.9 ± 1.8	3.6-7.2
Creatinine BF (μmol L^{-1})	74.4 ± 7.8	64.4 ± 7.1	63.0 ± 10.4	75.0 ± 21.7	64 ± 11.9	88.4-159
Creatinine AF (μmol L^{-1})	66.6 ± 6.9	64.6 ± 10.8	64.0 ± 13.8	64.8 ± 8.4	72.0 ± 15.6	88.4-159
Protein BF (g L^{-1})	67.2 ± 4.8	66.6 ± 4.2	64.4 ± 1.4	70.4 ± 2.8	66.6 ± 3.1	64-70
Protein AF (g L^{-1})	71.2 ± 5.3	64.2 ± 7.8	65.2 ± 3.1	68.0 ± 4.6	66.6 ± 2.4	64-70
Albumin BF (g L^{-1})	44.2 ± 0.8	42.2 ± 2.3	38.4 ± 3.7	44.6 ± 3.1	42.0 ± 2.5	27-39
Albumin AF (g L^{-1})	30.0 ± 3.3	28.2 ± 3.0	29.4 ± 1.3	29.2 ± 4.7	32.0 ± 0.7	27-39
Cholesterol BF (mmol L^{-1})	1.5 ± 0.6	2.0 ± 0.5	0.9 ± 0.6	1.7 ± 0.5	1.4 ± 0.3	2.1-3.4
Cholesterol AF (mmo L^{-1})	2.2 ± 0.6	2.0 ± 0.3	2.7 ± 0.4	2.2 ± 0.4	2.4 ± 0.5	2.1-3.4

BF: Before experimental period; AF: After experimental period; PGOT: Plasma Glutamic Oxaloacetic Transaminase; Plasma GPT: Plasma Glutamic Pyruvic Transaminase; Reference values (Kaneko *et al.*, 2008); $^{a\text{-}c}$Means in the same row with different superscripts are significantly different (p<0.05) according to Duncan's Multiple Range test

before and after 4 h of feeding (Table 5). Acetate concentration reduced (p<0.05) while propionate and butyrate percentages increased (p<0.05) with increasing concentrate levels in the diets. Before feeding, acetate proportion in the control and 0.6% C treatments recorded the highest values (76.0 and 74.8%, respectively) while the lowest value (59.1%) was recorded in the 2.4% C treatment. Conversely, the greatest propionate percentage was in the 2.4% C treatment (28.7%) and the lowest butyrate percentages were in the control and 0.6% C treatments (5.8 and 8.4%, respectively) which were significantly lower than in the other treatment groups. Similarly, after 4 h of feeding, the highest acetate concentration was found in the control and 0.6% C treatments (72.3 and 68.8%, respectively) which were greater (p<0.05) than the other treatments. Propionate values in treatments 1.8 and 2.4% C were higher (p<0.05)

than in other treatments (37.1 and 35.5%, respectively). The lowest proportion of butyrate was in the control treatment (6.7%) which was lower (p<0.05) than in the supplemented groups, which ranged between 10.5 and 15.1%.

Plasma metabolites: The values of plasma metabolites before the experimental period were highly variable (Table 6). Plasma Glutamic Oxaloacetic Transaminase (PGOT) and glucose concentrations were lower than the reference range in some treatments. Creatinine and cholesterol concentrations were lower than reference values in all treatments. Plasma Glutamic Pyruvic Transaminase (PGPT) values were higher than the normal range in all treatments (Table 6). However, after the experimental period, most of indices fell within the normal range, except for PGOT and creatinine which were lower and PGPT values higher than the reference values.

DISCUSSION

Feed intake and body weight gain: In this investigation, feed intake increased when goats were fed highlevels of concentrates in the diets. This is in agreement with Haddad (2005) who observed an increase in feed intake when the concentrate : forage ratios rose from 40:60-15:85. There was a substitution ofgrass intake for concentrate when concentrate consumption increased. This could be explained by the higher palatability and smaller volume of concentratescompared to forages. Moreover, grains produce less heat than forages (Mahgoub *et al.*, 2000) and this has an effect on feed intake of goats in regions with a hot climate. The goats were able to consume comparatively more concentrates than when fed grass only, thus increasing the total dry matter intake and consequently the ADG. Although, the total DM intake of goats in treatment 2.4% C was greater than in treatment 1.8% C, both treatments had the same Average Daily Gain (ADG) (150 g day^{-1}), indicating that there is a limit to the benefit of substituting grass with concentrates. In terms of economic efficiency, it would be more beneficial for Bach Thao goat farmers to supplement at 1.8% C and yet achieve the same growth levels as 2.4% C. Other researchershave observed similar results of increased feed intake and ADG as concentrate levels in the diets increased (Salim *et al.*, 2002; Haddad, 2005; Mushi *et al.*, 2009; Safari *et al.*, 2009).

Nutrient digestibility: When the proportion of concentrates in the diets increased, it resulted in higher DM, CP and OM digestibility. This is consistent with the findings of other investigators (Haddad, 2005; Cantalapiedra-Hijar *et al.*, 2009). The results of apparent digestibility of DM, OM and CP in the current experiment ranged between 59 and 81% and were higher than the 57-70% range reported by Haddad (2005). This might be due to differences in the type of ingredients used in ration formulation, which was reported by Cantalapiedra-Hijar *et al.* (2009) as a causal source of variation. It is well established that low pH of rumen fluid depresses fibre digestion (Grant and Mertens, 1992; Cerrillo *et al.*, 1999; Haddad, 2005). However, in this experiment, there was no differencein pH value between treatments after 4 h of feeding. This might be explained by the quick passage rate of concentrates through the rumen as the concentrates were offered and consumed before grass. Thus, no significant difference in NDF digestibility between the concentrate-supplemented groups was found.

Rumen fermentation: In the current study, the ammonia concentration (103.9-229.2 mg L^{-1}) was consistent withthe 100-200 mg L^{-1} range under tropical conditions (Leng, 1990). Ammonia concentrations in the 0.6 and 1.2% C treatments were higher than others at both points of measurement. This could be explained by the concentrate toforage ratios which the animals consumed. As the levels of consumed concentratesincreased, a greater amount of CP was consumed, thus leading to a faster rate of passage through the rumen and a higher turn-over of ammonia. Therefore, in treatments 1.8 and 2.4% C where goats consumed the highest amount of concentrates compared with the other treatments, rumen retention time was comparatively shorter than in other treatment groups. Consequently, the time of degradation by microbes was shorter; hence, less ammonia was detected in the rumen fluid.

The proportion of VFA reflects the nature of feeding. In this study, increased concentrate consumption resulted ina decrease in the proportion of acetate while propionate increased. This is in agreement with the findings of other authors (Dijkstra, 1994; Archimede *et al.*, 1996; Cantalapiedra-Hijar *et al.*, 2009). Moreover, propionate is mainly used by the host animal for the biosynthesis of glucose or deposition of body fat (Lu *et al.*, 2008). This could in turn explain the greater ADG of concentrate-supplemented groups.

Plasma metabolites: Plasma Glutamic-Oxaloacetic Transaminase (PGOT) activity has long been demonstrated as a reliable index of the onset and regression of nutritional muscular dystrophy (Hull and Scott, 1972). Therefore, alterations in the flux of PGOT can have consequences on muscle tissue growth. Similarly, creatinine levels are associated with growth, muscularity and total body protein mass (Hegarty *et al.*, 2006) while glucose is an index of dietary energy intake. It is logical to infer that the lower and highly variable levels of glucose, PGOT and creatinine before experimental supplementation were pointers to sub-optimal dietary energy and potentially low body protein mass, growth and muscular tissue development in the goats. However, these were restored to normality at the end of the supplementary period, an indication that amelioration was adequately achieved through concentrate supplementation.

CONCLUSION

Dietary concentrate supplementation of Bach Thao bucks at 1.8% C of body weight on dry matter basis had the best impact on growth performance, nutrient digestibility and rumen fermentation indices and may be recommended for application by local smallholder goat farmers in Vietnam.

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