

Nutritive values of selected forages for ruminants in
Vietnam. Supplementation of varying level of
cassava root meal and groundnut cake during
growing phase, and its effect on performance of
Laisind cattle in the finishing phase

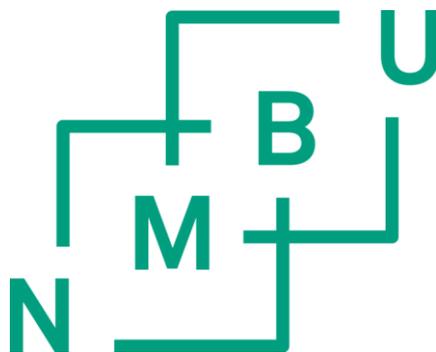
Næringsverdien i noen utvalgte fôrmidler for drøvtyggere i
Vietnam. Tilskudd av ulike nivåer av cassavarotmel og
jordnøttmel på produksjon hos storfe av rasen Laisind

Philosophiae Doctor (PhD) Thesis

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List of Abbreviations

ADF	acid detergent fiber
ATP	adenosine triphosphate
CP	crude protein
CRM	cassava root meal
DM	dry matter
DMI	dry matter intake
DOMI	digestible OM intake
EE	ether extract
EFM	efficiency of microbial synthesis
EPU	efficiency of protein utilization
FCR _{DM}	feed conversion ratio (kg DM/kg LWG)
FCR _{ME}	feed conversion ratio (MJ ME/kg LWG)
GNC	groundnut cake
IMF	intramuscular fat
IVDMD	<i>in vitro</i> dry matter digestibility
IVOMD	<i>in vitro</i> organic matter digestibility
LWG	live weight gain
ME	metabolizable energy
MJ	mega joule
MRT	mean retention time
N	nitrogen
NDF	neutral detergent fiber
NFE	nitrogen free extracts
NMIC	intestinal flow of microbial nitrogenous compounds
OM	organic matter
PDIA	the dietary protein undegraded in the rumen which is digestible in the intestine
PDIE	protein truly digestible in the small intestine when energy is the limiting factor
PDIN	protein truly digestible in the small intestine when N is the limiting factor
PER	protein efficiency ratio
RDP	rumen degradable protein
RE	retained energy
RFE	rumen fill effect
UFL	net energy value for milk production
UFV	net energy value for meat production
URTRS	urea treated rice straw
VFA	volatile fatty acids
WCW	warm carcass weight

List of Papers

This thesis is based on the following papers referred to by their roman numerals in the text.

Paper I

Trung, N.T., Berg, J., Cuong, V.C., Kjos, N.P., Nutritive values of selected forages used by traditional small farms in the northern Vietnam. *Manuscript*.

Paper II

Trung, N.T., Berg, J., Cuong, V.C., Kjos, N.P. (2014). Influence of varying levels of supplemental cassava root meal without or with groundnut cake on performance of growing Laisind cattle. *Tropical Animal Health and Production*. 46:925-930. DOI 10.1007/s11250-014-0586-5

Paper III

Trung, N.T., Berg, J., Cuong, V.C., Kjos, N.P., Varying supplemental cassava root meal without or with groundnut cake during growing phase impacts performance, carcass characteristics and meat quality of finished Laisind cattle. *Manuscript*.

Summary

In Vietnam, the demand on quantity and quality of beef has been increasing rapidly but the domestic production does not meet these demands. Vietnam had a production of 293 969 tons of beef cattle in 2012, and had imported 66,951 beef cattle from Australia for meat consumption in 2013. Speeding up domestic production sector is necessary to fulfill the gap of consumption requirement. The local Yellow and the Laisind (local Yellow x Sindhi) are the most common breeds of cattle in Vietnam. The local Yellow cattle have low average body weights, about 180-200 kg for mature females and around 300 kg for bulls, compared to Laisind cattle. These cattle are well adapted to the local climate and feeding conditions, heat tolerant, disease resistant and are fertile as well. The population of cattle are 27% and 41% in the North and Central of Vietnam, respectively. Number of cattle per householder is small, 89% of householder farm kept less than 5 animals in North Vietnam, 94% in North Central and 50% in South Central Coast; respectively. The limited feed resources for cattle were a major factor affecting herd size and cattle management on smallholder farms in the northern and central Vietnam. Feeding of cattle is largely based on pasture grasses, crop by-products and cultivated forages. The increasing demand for crop land results in reducing grazing areas. Moreover, fluctuation in quantity, quality and overgrazing in low land areas results in the use of natural grass is partly replaced by cultivated grass and crop by-products. During drought season, one major factor limiting growth by cattle is low quantity and quality of available pasture and many livestock producers fed cattle with rice straw-based diets, and maize stover silage. Finishing of beef cattle has been operated in some areas. The finishing regimes such as weight at starting, length of finishing period, amounts of concentrates offered, and slaughter weights depend on regions, breeds of cattle, availability of feeds. Therefore, the nutritive values of some selected forages for ruminants, supplementation strategies during growing phase (dry season) and its impact on performance of finishing cattle were studied in order to increase performance, carcass and meat quality of beef cattle.

The studies were divided into three experiments. Experiment I evaluated the nutritive values of selected forages for ruminants. Experiment II examined the effects of varying level of cassava root meal (CRM, 1000g and 300g) without or with groundnut cake (GNC, 700g) supplementation on performance of growing Laisind cattle. Experiment III assessed the influence of varying previous supplementation strategies on carcass and meat quality of finished cattle.

In experiment I, the PDIN (protein truly digestible in the small intestine when nitrogen is the limiting factor), PDIE (protein truly digestible in the small intestine when energy is the limiting factor), ME (metabolizable energy) and UFV (net energy for meat production) values of elephant grass cultivated under the same location and management reduced as aging, but dry matter (DM) intake of grass cutting at 75 days was highest compared to cutting at 45, 55 and 65 days. The DM intake was 35.6, 38.4, 36.5 and 43.0 g/kg $W^{0.75}$, PDIA (dietary protein undegraded in the rumen which is digestible in the intestine) values reduced from 37 to 26 g/kg DM; PDIN and PDIE reduced from 70 to 49, and 84 to 72 g/kg DM for cutting at 45, 55, 65 and 75 days; respectively. Their ME and UFV values declined linearly from 8.95 to 8.52 MJ/kg DM and 0.70 to 0.63 per kg DM; respectively. Elephant grass, harvested at the same age of regrowth (40, 50, 55 and 60 days) but from different locations and periods of time, showed wide variations in DM, crude protein (CP) contents, DM intake and digestibility as well as PDIN, PDIE, ME and UFV values. Their DM intake varied largely from 34.2 (40 days, May 2007) to 65.4 g/kg $W^{0.75}$ (60 days, September 2005). Their PDIN and PDIE was ranging from 57 (60 days, Sept 2005) to 105 (40 days, May 2005), and 75 (50 days, Aug. 2006) to 105 g/kg DM (40 days, May 2007); respectively. The ME and UFV value was ranging from 7.85 (50 days, Aug. 2006) to 9.72 MJ/kg DM (40 days, May 2007), and 0.55 (50 days, Aug. 2006) to 0.77 per kg DM (40 days, May 2007); respectively. The DM intake of natural grass was 50.4 g/kg $W^{0.75}$. The PDIN and PDIE value was 61 and 72 g/kg DM; respectively. The ME and UFV value was 8.36 MJ/kg DM, and 0.61 per kg DM; respectively. Maize stover had DM intake of 50.5 g/kg $W^{0.75}$, ME value was 8.90 MJ/kg DM and net energy (UFV) value of 0.66 per kg DM. Sweet potato vine had low DM content (150 g/kg DM) and DM intake (35.2 g/kg $W^{0.75}$), but the energy values were high, ME was 10.31 MJ/kg DM; and 0.88 and 0.85 for UFL (net energy for milk production) and UFV, respectively. Stylo grass had 79 g (PDIN), 80 g (PDIE) per kg DM; ME and UFV value was 7.38 MJ/kg DM, and 0.49 per kg DM, respectively. Maize stove silage had DM intake of 53.3 g/kg $W^{0.75}$, PDIN and PDIE value was 52 and 72 g/kg DM, ME and UFV value was 8.19 MJ/kg DM, and 0.59 per kg DM; respectively. Cassava tops silage had DM intake of 46.1 g/kg $W^{0.75}$ and its PDIN and PDIE value was 94g (PDIN), 79g (PDIE) per kg DM, ME and UFV value was 6.92 MJ/kg DM, and 0.46 per kg DM; respectively. The DM intake of Bermuda hay, natural grass hay and Guinea hay was 63.2, 62.8 and 51.6 g/kg $W^{0.75}$; respectively. Their PDIN and PDIE values was 45, 59 and 94 g (PDIN), and 71, 70 and 89 g (PDIE) per kg DM; ME and UFV value was 8.65, 7.35 and 7.64 MJ/kg DM, and 0.63, 0.50 and 0.52 per kg DM; respectively. Intake of urea treated rice straw (URTRS) and digestibility of neutral detergent fiber (NDF) decreased as

CRM level increased on the diets without GNC, but was not affected by CRM level on the diets with GNC in the experiment II. Total dry matter intake, feed conversion ratio (FCR) and live weight gain (LWG) improved as CRM level increased on the diets with GNC, but no difference was observed on the diets without GNC. In experiment III, cattle offered high level of CRM and GNC during growing phase had lower LWG and the higher feed conversion ratio (FCR), but had highest carcass weight, trimmed fat, edible meat and intramuscular fat (IMF) compared to the rest.

It is concluded that the advancing maturity of regrowth elephant grass (45, 55, 65 and 75 days) cultivated under the same condition increased DM intake, but reduced nutritive values. There were variables in DM intake and nutritive values of regrowth elephant grass at the similar ages, harvesting from different locations and years. Natural grass, maize stover, Stylo grass and maize stove silage were good quality feeds and their DM intakes were acceptable. Sweet potato vine was potential feed if its DM intake can be improved by wilting before feeding to animals. Cassava tops silage should be used as a protein supplemental source instead of feeding as a sole feed. Maize stove silage, Bermuda hay, natural grass hay and Guinea hay had medium quality but DM intake were good. Supplementation of 1000g CRM should be in combination with 700g GNC to avoid the negative effects on URTRS intake and digestibility, therefore improve LWG of growing Laisind cattle fed on a URTRS-based diet. The coming cattle for finishing phase should be supplemented with high CRM and GNC during growing phase in order to increase IMF content, carcass weight and edible meat of finished cattle.

Sammendrag (Summary in Norwegian)

I Vietnam har etterspørselen av kjøtt fra storfe, både når det gjelder kvantitet og kvalitet, økt de siste årene. Den innenlandske produksjonen oppfyller imidlertid ikke disse behovene. Vietnam hadde en produksjon på 293 969 tonn storfe i 2012 og importerte 66 951 storfe fra Australia for å dekke kjøttforbruket i 2013. Det er nødvendig å øke innenlandsk produksjon for å dekke etterspørselen. De lokale storferasene Yellow og Laisind (Yellow x Sindhi) er de vanligste i Vietnam. Yellow har lav gjennomsnittlig kroppsvekt, ca 180-200 kg for kyr og rundt 300 kg for slaktemodne okser. Rasene er godt tilpasset lokalt klima og beiteforhold, de er varmetolerante, motstandsdyktige mot sykdom og har god fruktbarhet. Av den totale storfebestanden er 27% lokalisert i Nord-Vietnam og 41% i sentrale deler av Vietnam. Antall storfe per gårdbruker-familie er liten, ca. 90% av gårdene har mindre enn fem dyr i Nord-Vietnam. Begrensede fôrressurser til storfe er en viktig faktor som påvirker buskapsstørrelse. Fôringener i stor grad basert på beite, biprodukter fra planteproduksjon og dyrket fôr. Den økende etterspørselen etter dyrket areal resulterer i reduserte beitearealer. Variasjoner i avlingsmengde og kvalitet, samt overbeiting, resulterer i at bruken av naturlige beiter er delvis erstattet av dyrket beite og biprodukter fra planteproduksjonen. Under tørkeperioden er lav kvalitet og mengde av tilgjengelig beite en viktig faktor som begrenser tilvekst, og mange husdyrprodusenter fôrer med rasjoner basert på rishalm og surfôr av blader og stengel av mais («maize stover silage»). Slutfôring av storfe er benyttet i enkelte områder. Vekt ved innsett, lengde på slutfôringsperioden, mengde kraftfôr og slaktevekt varierer mellom regioner, rase og tilgjengeligheten av fôr.

For å øke tilvekst, samtforbedre slakte - og kjøttkvalitet, ble det gjennomført forsøk for å studere næringsverdien av noen utvalgte fôrmidler, og effekt av tilskuddsfôr i vekstfasen av oppdrettet, samt i slutfôringsperioden. Studiene ble delt inn i tre forsøk. Forsøk I evaluerte næringsverdien av utvalgte fôrmidler. Forsøk II undersøkte effekten av ulike mengder (1000 g og 300 g) av kassavarot (CRM) med jordnøttmel (700 g) - eller uten jordnøttmel på ytelsen hos voksende Laisind storfe. Forsøk III vurderte påvirkning av tidligere tilskuddsstrategier på slakte - og kjøttkvalitet.

I forsøk I ble PDIN (sann fordøyelig protein i tynntarmen når nitrogen er den begrensende faktor), PDIE (sann fordøyelig protein i tynntarmen når energi er den begrensende faktor), ME (omsettelig energi) og UFV (nettoenergi kjøttproduksjon) verdier av elefantgras dyrket under samme forhold analysert. Ved utsatt høsting ble PDIN, PDIE, ME og UFV redusert. Fôropptaket i tørrstoff (TS) var høyest når gras ble høstet etter 75 dager sammenlignet med

høsting etter 45, 55 og 65 dager. Tørrstoffopptaket var 35,6, 38,4, 36,5 og 43,0 g/kg $W^{0.75}$. Videreble PDIA (nedbrutt fôrprotein fra vomma som blir fordøyd i tarmen) redusert fra 37 til 26 g/kg TS, mens PDIN og PDIE ble redusert fra 70 til 49, og fra 84 til 72 g/kg TS ved høsting 45, 55, 65 og 75 dager. ME og UFV verdiene ble lineært redusert fra 8,95 til 8,52 MJ/kg TS og fra 0,70 til 0,63 per kg TS. Elefantgras høstet på samme alder på gjenveksten, men fra ulike lokaliteter viste stor variasjon i TS og råproteininnhold, TS inntak og fordøyelighet, samt PDIN, PDIE, ME og UFV. Tørrstoffinntaket varierte fra 34,2 (40 dager, mai 2007) til 65,4 g/kg $W^{0.75}$ (60 dager, september 2005). PDIN og PDIE varierte henholdsvis fra 57 (60 dager, september 2005) til 105 (40 dager, mai 2005), og fra 75 (50 dager, august 2006) til 105 g/kg TS (40 dager, mai 2007). ME og UFV varierte henholdsvis fra 7,85 (50 dager, august 2006) til 9,72 MJ/kg TS (40 dager, mai 2007), og fra 0,55 (50 dager, august 2006) til 0,77 per kg TS (40 dager, mai 2007). Tørrstoffopptaket av naturlig gras var 50,4 g/kg $W^{0.75}$. PDIN og PDIE var henholdsvis 61 og 72 g/kg TS. ME og UFV var tilsvarende 8,36 MJ/kg TS og 0,61 per kg TS. Mais («maizestoversilage») hadde et tørrstoffopptak på 50,5 g/kg $W^{0.75}$, ME på 8,90 MJ/kg TS og en nettoenergi (UFV) på 0,66 per kg TS. Søtpotet-blader («sweetpotatovine») hadde lavt TS innhold (150 g/kg TS) og tørrstoffopptak (35,2 g/kg $W^{0.75}$), men energiverdiene var høye. ME var 10,31 MJ/kg TS, UFL (nettoenergi til melkeproduksjonen) 0,88 og UFV 0,85. «Stylograss» hadde 79 g PDIN og 80 g PDIE per kg TS, mens ME og UFV var henholdsvis 7,38 MJ/kg TS og 0,49 per kg tørrstoff. Mais («maize stover silage») hadde tørrstoffinntak på 53,3 g/kg $W^{0.75}$, PDIN og PDIE var 52 og 72 g/kg TS mens ME og UFV var 8,19 MJ/kg TS og 0,59 per kg TS, henholdsvis. Kassava («cassavatoppsilage») hadde tørrstoffopptak på 46,1 g/kg $W^{0.75}$, 94 g PDIN og 79 g PDIE per kg TS, mens ME og UFV var henholdsvis 6,92 MJ/kg TS og 0,46 per kg TS. Tørrstoffinntaket av høy fra Bermudagrass, høy av naturlig gras og høy av Guinea-gras var henholdsvis 63,2, 62,8 og 51,6 g/kg $W^{0.75}$. Deres PDIN og PDIE verdier var henholdsvis 45, 59 og 94 g (PDIN), og 71, 70 og 89 g (PDIE) per kg TS. ME og UFV verdiene var tilsvarende 8,65, 7,35 og 7,64 MJ/kg TS og 0,63, 0,50 og 0,52 per kg TS. Opptak av ureabehandlet rishalm (URTRS) og NDF fordøyelighet ble redusert ved høyere innhold av kassavarotmel (CRM) i rasjoner uten jordnøttmel (GNC), men ble ikke påvirket av innhold av kassavarotmel i rasjoner med jordnøttmel (forsøk II). Totalt opptak av tørrstoff, fôrforbruk (FCR) og tilvekst (LWG) ble forbedret med økende innhold av kassavarotmel når rasjonen også inneholdt jordnøttmel, men ingen forskjell ble observert på dietter uten jordnøttmel. Storfe som fikk tilskudd av både kassavarotmel og jordnøttmel i vekstperioden hadde lavere tilvekst i den etterfølgende sluttføringsperioden og et høyere fôrforbruk (FCR), men oppnådde høyest slaktevekt, mer fett

på slaktet, høyere andel spiselig kjøtt og mer intramuskulært fett (IMF) sammenlignet med de andre gruppene.

Det konkluderes med at økende alder ved høsting av elefant-gras, fra 45 til 75 dagers alder, øker opptaket av tørrstoff, men reduserer næringsverdien. Det var variasjon i opptak av tørrstoff og næringsverdi av gjenvekst av elefant-gras, høstet ved samme aldermen fra ulike steder og år. Naturlig gras, mais («maize stover silage») og Stylo-grasga fôr av god kvalitet og med et akseptabelt opptak av tørrstoff. Søtpotet-blader («sweetpotatovine») har potensial som fôr hvis tørrstoffopptaket kan forbedres ved tørking før fôring. Kassava («cassavotopssilage») bør brukes som et protein supplement i stedet for som eneste fôr. Mais («maize stover silage»), høy av Bermuda-gras, høy av naturlig gras og høy av Guinea-gras hadde middels kvalitet, men opptaket av tørrstoff var bra. Tilskudd av 1000g kassarotmelbør gis i kombinasjon med 700g jordnøttmel for å unngå negativ virkning på opptaket og fordøyeligheten av ureabehandlet rishalm. Dette vil gi høyere tilvekst hos voksende Laisind storfe fôret med ureabehandlet rishalm som basisfôr. Storfe som skal på slutfôringbør suppleres med kassavarotmel og jordnøttmel i vekstfasen for å øke slaktevekt, andel spiselig kjøtt og innhold av intramuskulært fett i kjøttet.

INTRODUCTION

The demand of beef in general, and beef of high quality is increasing rapidly in Vietnam recently but the domestic production does not meet these demands. Vietnam had a production of 293 969 tons of beef meat (Ministry of Agriculture and Rural Development, 2014) in 2012; and had imported 66,951 beef cattle from Australia for meat consumption in 2013 (Beef Central, 2014). To reduce this extensive import of beef, it is necessary to speed up domestic production.

The local Yellow and the Laisind (Sindhi x local Yellow) are the most common breeds of cattle in Vietnam. The local Yellow cattle have low average body weights, about 180-200 kg for adult females and around 300 kg for bulls (Burns *et al.*, 2002). These cattle are well adapted to the local climate and feeding conditions, heat tolerant, disease resistant and have a good fertility as well. Some breeding programs have been initiated in order to select beef cattle, including crossbred and native cattle, for sires and dams. Weights and body conformation were the criteria for selection. Since 1920's the first program started with the crossing of local Yellow cattle with Red Sindhi imported from Pakistan (Su and Binh, 2002). The authorities reported that the body weight of this "Laisind" crossbred was 30-35% higher, meat production 5-8% higher and draught power 20% higher compared to local Yellow cattle. The Red Sindhi is often used by farmers as a first cross (F1) when attempting to increase the size of their animals. Although fertility rates in these cattle are good, the growth rates and profit margins are typically low. Later the breeding program focused on fattening and economic comparisons of beef breeding in different economic zones. The national program under the "Beef Cattle Development Project-VIE/86/008" lasted between 1989 and 1991. Some new crosses were introduced, with *Bos taurus* breeds, such as Brahman or Sahiwal crossed with the "Laisind" breed. In 1996 a program entitled "Profitable Beef Cattle Development in Vietnam (AS2/97/18)" was started by the Australian Centre for International Agricultural Research (ACIAR). An important goal of this project was to find outcomes which increase the profitability of cattle rearing by smallholder farmers, rather than assessing results only in terms of physical production or productivity measures. This project has focused on developing a crossbreeding program to produce a mid-sized, 'easy care' animal with good growth and good fertility, while remaining well-adapted to the local environmental stresses (Burns *et al.*, 2002). The project "Improved Utilization of by-products for Animal Feeding in Vietnam" funded by the Norwegian Programme for Development, Research and Education

(NUFU), from 1996 until 2001, had been carried out with numerous research and mainly focused on utilization of locally available feed resources for proper feeding of beef cattle.

Cattle are rearing in the North and Central of Vietnam, 27% and 41%, respectively (Ministry of Agriculture and Rural Development, 2014). Number of cattle per householder is small, 89% of householder farm kept less than 5 animals in North Vietnam, 94% in North Central and 50% in South Central Coast; respectively (Tung, 2009). Huyen *et al.* (2011) reported that limited feed resources for cattle was a major factor affecting herd size and cattle management on smallholder farms in the northern Vietnam. Feeding of cattle is largely based on pasture grasses, crop by-products and cultivated forages. The increasing demand for crop land results in reduced grazing areas. Moreover, variation in quantity, quality and overgrazing in low land areas results in the use of natural grass is partly replaced by cultivated grass and crop by-products. Nutritive values of forage vary largely and depend on many factors such as species, maturity, soil fertility, fertilizer application, and seasons as well. Understanding the variation in nutritive values those exist is important in formulating feeding systems and explaining variation in livestock production to different strategies. In beef production, about 60% of total costs in achieving a marketable steer are attributed to feed expenses (Ritchie, 1992). There is limited published information on nutritive values of the common feed used by householders in northern Vietnam.

One major factor limiting growth of cattle during the drought season is low quantity and quality of available pasture (Tung, 2009). During this time, many livestock producers fed cattle with rice straw-based diets, and maize stover silage (Huyen *et al.*, 2011). Rice straw is low in nutritive value and has a poor digestibility. In a number of treatment methods, chemical treatments such as urea or ammonia currently seem to be more practical for on-farm use (Sarnklong *et al.*, 2010). Urea-ammoniated rice straw has higher CP content and digestibility (Van Soest, 2006) as well as higher intake, thus resulted in enhanced performance of ruminants as compared to untreated rice straw (Trach, 2004; Wanapat *et al.*, 2009). Supplementation with locally available feed resources such as cassava root meal, rice bran, or groundnut cake is common but the amounts are varying among householders and regions. Studies examine the effects of supplementation of energy and proteins on performance of growing cattle are limited.

Finishing of beef cattle has been operated in some areas. The finishing regimes such as weight at starting, length of fattening period, amounts of concentrates offered, and slaughter weights depend on regions, breeds of cattle, and availability of feeds. The initial weight enters finishing are around 180 kg BW, fattening from 2.0 to 4.5 months, and concentrate are 1.4 to

2.9 kg DM per day, live weight gain (LWG) was from 0.43 to 0.77 kg per day, and slaughter weight from around 230 to 355 kg BW (Dung *et al.*, 2013; Stür *et al.*, 2013). Most of local Yellow cattle are sold as ‘calf beef’ aged 12-18 months because of their poor LWG and low mature slaughter weight. Farmers tend to use more Laisind and cross-bred (Laisind × exotic breeds such as Brahman or Droughtmaster) cattle; they fattened younger animals that required a longer fattening period; achieved a higher slaughter weight and a higher weight gain (Stür *et al.*, 2013). The effects of previous supplementation strategies and growth rate on finished Laisind cattle have not been determined.

1.1 Nutritive values of forage and INRA system

1.1.1 Using INRA system to investigate nutritive values of forages

The potential of forage for ruminant production, or its feeding value, is determined by the quantity of digestible organic matter or net energy which is consumed when it is fed *ad libitum* as the sole food. This depends on the apparent digestibility of organic matter and on the voluntary intake characteristics, referred to as the ingestibility of the forage (INRA, 1989). Knowledge of these parameters is a prerequisite to the best use of forage resources and to their efficient combination with concentrates (INRA, 1989). The equations used in nutritive value determination of experimental feedstuffs according to the INRA system has been used in Vietnam for more than ten years and the available database has been fitted to these equations (Vu *et al.*, 2011).

In vivo digestion is the most accurate method to measure nutritive values of forages. Recently, there has been few published information on nutritive values of ruminant feeds used by smallholder farmers in Vietnam.

1.1.2 Factors affecting forage quality, intake and digestion

In the tropics forage quality usually limits productivity of cattle due to its low quality. There are main factors affecting forage quality, intake and digestion.

1.1.2.1 Genotype (forage species)

Legumes are of higher forage quality and their digestibility decreases over time at a slower rate than the digestibility of grasses (Buxton, 1996; Ball *et al.*, 2001). Legume leaves contain much less cell wall than do leaves of grasses, and legume leaves do not exhibit the increase in cell-wall concentration associated with maturation of the plant that occurs in grass leaves (Wilman and Altimimi, 1984). Legume intake is generally higher than grass intake because legumes have lower cell-wall contents, higher CP concentrations and faster rates of particle-

size reduction in the rumen, and faster organic matter (OM) removal from the rumen (Rook *et al.*, 2002).

1.1.2.2 Age of regrowth (maturity)

Maturity is considered to be the primary factor affecting the chemical composition and nutritive value of most forage (Nelson and Moser, 1994). The decline in forage quality with age results primarily from a decrease in leaf:stem ratio and decline in quality of the stem fraction due to an increase in the proportion of cell wall and its lignification (Mtengeti *et al.*, 1995; Wilman and Moghaddam, 1998; Ngo and Wilkitorsson, 2003). Additionally, as plants advance in maturity their cell wall content increases (Sleugh *et al.*, 2001; Yu *et al.*, 2004). Another reduce in forage quality is due to reduction in nitrogen concentration. As forages advance in maturity the CP content decreases (Merchen and Bourquin, 1994; Yu *et al.*, 2004; Abbasi *et al.*, 2012). The reduction of CP content with increased maturity was related to a decline in the portion of leaves in the forage biomass, which has a higher CP concentration (Freer and Dove, 2002). Decrease in nitrogen (N) concentration with advanced maturity is likely attributed to N translocation from aboveground biomass to belowground organs between the time of anthesis and after a killing frost (Vogel *et al.*, 2002). Plants use this translocated N for producing new growth the following next spring (McKendrick *et al.*, 1975).

As forage grow and mature they pass through a succession of growth stages; from a nutritional viewpoint, these may be classed as vegetative, prebloom, early bloom, full bloom, milk stage, dough stage, mature, and overripe (Minson, 1990). These changes in maturity are accompanied by increase in the proportion of leaf, and a fall in intake. The fall in intake is caused by three factors: an increase in the proportion of stem (which is eaten in smaller quantity than leaf), a fall in intake of both leaf and stem fraction, and nutrient deficiencies in the mature forages.

As forages mature there is a rise in fiber concentration. Intake was negatively correlated with crude fiber content. Fiber depresses intake through its effect on the resistance of the forage to chewing during eating and ruminating. Confirmation of the dominant role of chewing in limiting intake is the increase that is achieved by grinding and pelleting, a process which overcomes the need for the animal to break down forage particles to a size that can readily leave the rumen.

The intake of both leaf and stem fractions decreases as the forage matures. This decrease in intake was associated with increase in lignin, grinding energy, and the time leaf and stem were in the rumen. Intake and digestibility depend on the rates of NDF digestion and feed

particle breakdown in the rumen and on the rate of digesta outflow from the rumen (Mertens, 1993). Kaura *et al.* (2011) reported that rate of degradation of fiber decreased from week 7 until 13 in forage rape leaf (0.21–0.08/h), petioles (0.12–0.03/h) and stem (0.09–0.01/h). In ruminants fed forage-based diets it is assumed that intake is regulated by rumen fill which is determined by NDF intake (Van Soest, 1994). Compared with others feed fractions, indigestible fiber has a higher retention time in the reticulum-rumen and thus it has a stronger association with rumen fill and forage intake (Allen, 1996). Vieira *et al.* (1997) indicated that the increase in the NDF undegradable fraction was associated with the stem proportion as the plants grew. The rise in the NDF undegradable fraction was associated with the increase in the mean retention time (MRT) of forage particles, resulting in a higher rumen fill effect (RFE) of this nutrient (Vieira *et al.*, 1997). Another possible cause of the low voluntary intake (VI) of mature forage is a nutrient deficiency, most commonly protein. The deficiency can be overcome, and VI increased, by applying fertilizer nitrogen or feeding a protein supplement.

Maturity at harvest is considered to be the major factor affecting forage quality including decreased *in vitro* dry matter digestibility (IVDMD) and crude protein, and increased NDF concentrations (Waramit *et al.*, 2012). Maturity and subsequent changes in the chemical composition of forages are usually closely associated with a decrease in digestibility (Nelson and Moser, 1994). Cell walls became more resistant to breakage with maturity and/or that the proportion of soluble constituents in the forage cell wall (Casler and Hatfield, 2006) declined with maturity. Van Soest (1994) observed a negative curvilinear relationship between lignin concentration and NDF digestibility but not with DM digestibility of forages. Content of NDF greater than 60% is known to result in decreased voluntary feed intake, increased rumination time and decreased efficiency of conversion of metabolizable energy to net energy (Shirley, 1986; Reed and Goe, 1989). Postponing the harvest decreased the digestibility of Timothy/meadow fescue (*Phleum pratense* L./*Festuca pratensis* Huds.) and tall fescue (*Festuca arundinacea* Schreb.) silages harvested at three different cutting times (Särkijärvi *et al.*, 2012).

1.1.2.3 Plant parts

Leaf material is generally much higher in digestibility, is lower in fiber, and has twice as much crude protein as stem tissue from the same plant (Collins and Fritz, 2003). Kaura *et al.* (2011) indicated that the relatively high CP, and lower fiber contents, as well as the faster ruminal degradation of leaf > petiole > stem, primarily a consequence of the lower fiber content and higher digestibility of the fiber in leaf versus the other fractions.

1.1.2.4 Seasons, weather conditions

Chemical composition of forages is affected by weather conditions (Van Soest, 1996; Jouven *et al.*, 2006). Increased ADF concentrations were positively correlated with higher temperatures for bermudagrass and bahiagrass (Henderson and Robinson, 1982). Grimaud *et al.* (2006) reported an increase in dry matter concentration and a decrease in nutritional value of three tropical grasses (*Bothriochloa pertusa*, *Cynodon plectostachyus* and *Ischaemum aristatum*) at the end of the dry season compared to those at the rainy, and at the beginning of dry season.

Summer regrowth may have lower quality because high temperature increases lignification and promotes higher metabolic activity in plants (Van Soest, 1994). Rising temperature leads to increased rates of plant development, alterations of plant chemical composition, and to reductions of the leaf/stem ratio and digestibility (Buxton, 1996; Ansquer *et al.*, 2009). Wilson *et al.* (1991) concluded that high temperature during growth increased intensity of lignification of the existing lignified cells. Elgersma *et al.* (2013) reported that a strong negative relation between *in vitro* organic matter digestibility (IVOMD) and mean air temperature during regrowth was observed for eight species of grasses; four non-leguminous forbs [salad burnet (*Sanguisorba minor*), caraway (*Carum carvi*), chicory (*Cichorium intybus*) and ribwort plantain (*Plantago lanceolata*)] and three leguminous forbs [yellow sweet clover (*Melilotus officinalis*), lucerne (*Medicago sativa*) and birdsfoot trefoil (*Lotus corniculatus*)].

Moderate water deficit slows plant maturation, and if it does not cause severe leaf loss, forage quality and digestibility can be maintained or even slightly improved (Buxton, 1996; Reddy *et al.*, 2003). However, long and extreme drought events inhibit tillering and branching, accelerate the death of tillers and senescence of leaves, and relocate protein, nitrogen, and soluble carbohydrates from leaves to roots, reducing the nutritive value of the plant (Buxton, 1996; Durand *et al.*, 2010). Drought also affects the nitrogen nutrition of aboveground plant parts due to reduced uptake and use of soil mineral nitrogen (Durand *et al.*, 2010). Nonetheless, protein content was found to increase under drought in plants in symbiosis with arbuscular mycorrhizal fungi (Subramanian and Charest, 1995). In some species, sugar and proline are accumulated with water stress, the latter improving the recovery of plants from drought (Saglam *et al.*, 2008).

1.1.2.5 Fertilization (management)

Abbasi *et al.* (2012) reported that increasing N fertilization increased yield, CP concentration and nutrient digestibility. Johnson *et al.* (2001) noted that as fertilization level increased, total

N concentration increased ($P < 0.01$) linearly and NDF decreased linearly ($P < 0.01$) in three tropical forage species, Bermuda grass (*Cynodon dactylon*), star grass (*Cynodon nlemfuensis*) and Bahia grass (*Paspalum notatum*).

Proper N fertilization of warm-season grasses generally increases CP (Puoli *et al.*, 1991), but the effect of N fertilization on IVDMD and NDF is variable. Horn *et al.* (1979) demonstrated that intake and digestibility were not affected by N fertilization. Higher N rates tended to increase the NDF concentrations of the plant in wetter years resulting from change in the leaf:stem ratio in favor of less digestible stems (Buxton and Fales, 1994; Coleman *et al.*, 2004). In contrast, Rhykerd and Noller (1974) and Rhykerd and Noller (1974) reported that higher N rates provided to delay plant maturity for later harvests and in turn increased total plant digestibility.

1.1.2.6 Processing (Drying, Ensiling)

Natural drying of forage, after cutting, in the field leads to losses of dry matter by respiration and leaf shatter, resulting in more stemmy material and hence reduces intake (Minson, 1990).

Mayne and Cushnahan (1994/1995) reviewed all available literature and showed that, on average, silage intake was 27% less than intake of the same forage fed without ensiling. Rooke (1995) indicated that lactic acid may have a direct effect on palatability, because sour taste is associated with reduced palatability. Charmley (2001) suggested that many factors previously thought to reduce silage intake, such as pH, lactic acid and dry matter (DM), have, in fact, only a casual relationship with intake.

1.2 Supplementation of growing cattle

Ruminants consuming tropical agricultural by-products often require supplementation to achieve acceptable levels of production. The effect of supplementation on intake and digestion, however, is variable and affected by forage quality and supplement type (Moore *et al.*, 1999).

1.2.1 Supplementation of cassava root meal (CRM)

Cassava (*Manihot esculenta*, Crantz) is an annual root crop grown widely in tropical and subtropical areas. Cassava root meals (CRM) have low levels of CP but contain high level of starch, around 80 percent (Aryeea *et al.*, 2006; Mejía-Agüero *et al.*, 2012), which provides readily fermentable energy for fermentation in the rumen (Wanapat, 2009).

1.2.1.1 Supplementation with high levels of CRM

1.2.1.1.1 High levels of starch impact digestion and intake

Increasing the concentration of non-structural carbohydrates (mainly starch and sugar) in the diet has frequently been shown to decrease fiber digestion. Decreases in the rate of cell wall digestion with increased supply of non-structural carbohydrates has been attributed mainly to lower ruminal pH, because cellulolytic bacteria are more sensitive to low pH than those utilizing starch (Russell and Dombrowski, 1980). *In vitro* (Grant and Mertens, 1991) and *in situ* data (Mould *et al.*, 1983) suggest that rumen pH affect digestion kinetics in a biphasic manner. Above pH 6.2, the effects of pH on ruminal cell wall digestion are relatively small. But at a lower pH the effects are much stronger. Studies using continuous cultures allowing for independent changes in pH and level of rapidly degradable carbohydrates showed that the level of the rapidly degradable carbohydrates was the most important for fiber digestibility (Weisberg *et al.*, 1999). CRM has high starch content (Mejía-Agüero *et al.*, 2012) and is extensively and rapidly fermented in the rumen (Chanjula *et al.*, 2003).

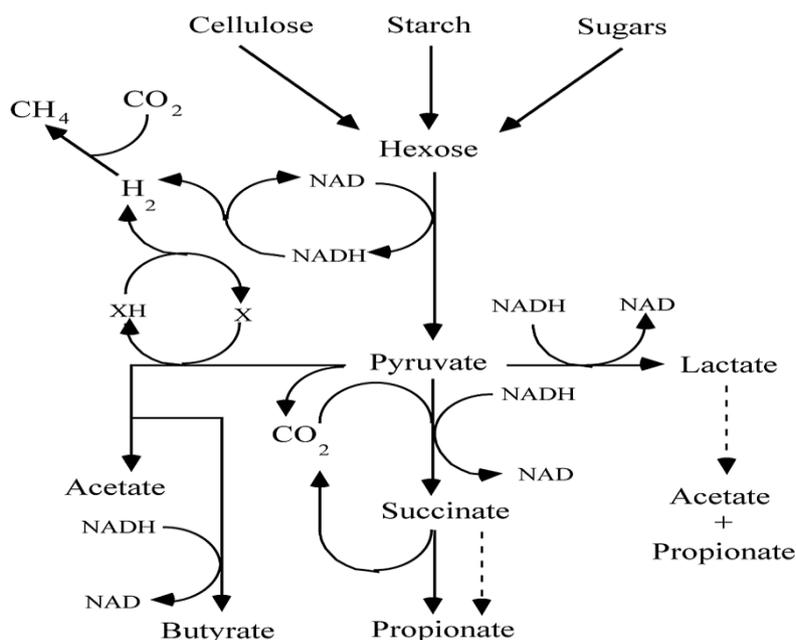


Fig. 1. A schematic showing the major pathways of carbohydrate (starch) fermentation by ruminal bacteria. “X” denotes alternative electron carrier (e.g., ferredoxin). In some ruminal bacteria, pyruvate decarboxylation is coupled to formate production, but most of this formate is converted to hydrogen and carbon dioxide by hydrogen formate lyase. The dashed lines show pathways that occur in other organisms. From Russell and Rychlik (2001).

When cattle are switched abruptly from forage to grain, the rumen can become severely acidic (ruminal pH, 5.5), and this acute acidosis is caused by the overgrowth of starch-

fermenting, lactate-producing bacteria (*S. bovis* and *Lactobacillus* spp.) (Owens *et al.*, 1998). If the dietary shift is gradual, *M. elsdenii* and *Sel. ruminantium* can convert lactic acid to acetate and propionate (Fig. 1), the ruminal pH is not as severely affected (Owens *et al.*, 1998), and the ruminal ecology is not so drastically altered (Tajima *et al.*, 2000). However, even high concentrations of volatile fatty acids can cause subacute ruminal acidosis (Owens *et al.*, 1998), and pH-sensitive ruminal bacteria (e.g., cellulolytics) are inhibited if the ruminal pH is lower than 6.0 (Russell and Wilson, 1996).

Inhibition of growth by low pH is related to intracellular pH regulation (Russell and Wilson, 1996). When extracellular pH is low, intracellular pH of acid-resistant fermentative bacteria (*S. bovis*, *Prevotella ruminicola*, *Clostridium aminophilum*, and *Sel. ruminantium*) declines, which protects them from the influx and accumulation of fermentation acid anions (Russell, 1991). In contrast, ruminal cellulolytic bacteria (e.g. *F. succinogenes*) attempt to maintain a constant intracellular pH, but this leads to a large transmembrane pH gradient. Because undissociated volatile fatty acids can freely pass into the more alkaline interior, there is a logarithmic and toxic accumulation of intracellular volatile fatty acid anions (Russell and Wilson, 1996; Russell and Diez-Gonzalez, 1998).

Cellulolytic activity can be impaired by others factors independently of pH, including a specific induced-starch inhibitory effect (Heldt *et al.*, 1999; Arroquy *et al.*, 2004a) or sugar toxicity for cellulolytic bacteria (Russell, 1998). High starch supplementation reduced fiber digestion of diets which are attributed to increased lag phase of fiber digestion (Huhtanen *et al.*, 2008) and a decrease in the rate of NDF digestion (Souza *et al.*, 2010), exacerbated microbial competition for available nitrogen (Arroquy *et al.*, 2004a). However, Kozloski *et al.* (2006) observed a linear decrease in NDF digestibility as increasing CRM supplement at 5, 10 and 15g/kg body weight (BW) of lambs even when nitrogen was not limiting for rumen bacteria.

Reduction in NDF digestibility is a primary cause of substitution of supplement for forage (Dixon and Stockdale, 1999). Olson *et al.* (1999) showed that forage DM intake was depressed by 0.12% BW when increasing starch supplement from 0.15% BW to 0.30% BW. Intake of Napier grass reduced linearly with increasing CRM levels in sheep (VanEys *et al.*, 1987). Olson *et al.* (1999) reported that forage DM intake was depressed by an average of 0.29 % of BW when starch was supplemented at 0.15% of BW and by 0.41% of BW when starch was supplemented at 0.3% of BW. Other studies (Klevesahl *et al.*, 2003; Kozloski *et al.*, 2007) also noted reduced forage intake with supplementation of starch.

1.2.1.1.2 High levels of starch affect live weight gain (LWG)

In the absence of nitrogenous compounds, starch supplementation decreased the efficiency of microbial synthesis (EFM, grams microbial CP per kilogram digestible organic matter (DOM)) and not increased intestinal flow of microbial nitrogenous compounds (NMIC, g/d) (Souza *et al.*, 2010). However, when diet is deficient in nitrogenous compounds, one can expect to observe a net gain of nitrogen in the rumen due to recycling (NRC, 2001). This process could support the high estimate of EFM.

When there is a deficiency of nitrogenous compounds, the inclusion of highly degradable carbohydrates in the diet can increase microbial energy spilling (dissipating excess ATP energy as heat). This behaviour is mediated by the futile cycling of protons through the cell membrane and is activated by ATP synthase. Due to high ATP hydrolysis, the microbial cells can increase the protonmotive force which decreases the membrane resistance to protons and thus increases futile cycling (Russell, 2002). For animals fed grain, N in the rumen is present but low, creating carbohydrate excess (NRC, 2000). If N is chiefly in the form of ammonia, carbohydrate excess could be intensified (Van Kessel and Russell, 1996) because rumen microbes grow far slower with ammonia-N than amino-N (Argyle and Baldwin, 1989; Van Kessel and Russell, 1996).

Rumen microbes respond to carbohydrate predominantly by synthesis of reserve carbohydrate, without spilling, under small excesses of carbohydrate (Hackmann *et al.*, 2013). Increasing offered amounts of concentrate (0, 1, 2 and 3% of BW) containing high level of CRM to cattle fed on URTRS had resulted in enhanced EFM at 1 and 2% of BW, but decreased EFM at 3% of BW compared to 0% (Wanapat and Khampa, 2007).

1.2.1.1.3 Supplementation of low levels of CRM (starch)

Low levels of grain or starch supplementation have not depressed straw intake, and have increased the extent of digestion of dietary cell wall constituents (Zorrilla-Rios *et al.*, 1989; Farmer *et al.*, 2001; Zhang *et al.*, 2010). Pordomingo *et al.* (1991) reported that grain supplements that delivered starch in amounts less than 0.15% of BW occasionally stimulated DM intake of low-quality forage. It was suggested that addition of a low level of readily fermentable carbohydrate in the rumen could short the lag time and stimulate fiber digestion by increasing bacterial numbers (Hiltner and Dehority, 1983) and by promoting formation of glycocalyx attachment structures (Demeyer, 1981), or by supplying deficient nutrients or a readily fermented cell wall substrate for cellulolytic bacteria (Bowman *et al.*, 1991). However, there is often a decrease in performance when ruminants are supplemented low levels of starch

compared to those supplemented higher levels (Ba *et al.*, 2008; Thang *et al.*, 2010b), attributed to lack of energy.

1.2.2. Supplementation of both CRM and groundnut cake or other protein sources

Groundnut cake is a by-product of extracting oil industry and is a locally available protein source. Its price is reasonable compared to other true protein sources (i.e. oilseed and fish meals) in Vietnam. Groundnut cake has rumen degradable protein (RDP) of around 80 percent of total protein (NRC, 2000; Mondal *et al.*, 2008) suggesting that groundnut cake supplementation act both ruminal and post-ruminal. Supplementation of RDP (i.e. casein) overcome negative effects of supplemental starch on fiber digestion of low quality forage (Klevesahl *et al.*, 2003). Arroquy *et al.* (2004b) found that forage intake, cattle performance and NDF digestion with true protein supplements was generally higher than those of cattle receiving non-protein nitrogen supplements. Total or partial substitution of urea for true protein in supplements may decrease microbial activity in the rumen, with a consequent depression in fiber digestion due to the limitations of microbial growth factors such as peptides, amino acids, and essential volatile fatty acids (VFA) (Cotta and Russell, 1982; Merry *et al.*, 1990). Rumen branched-chain volatile fatty acids (i.e., isobutyrate, isovalerate and 2-methylbutyrate) are essential nutrients for fiber-degrading bacteria and are created by deamination of valine, leucine and isoleucine (Van Soest, 1994). In the experiment supplementation of CRM with different protein sources (calcium caseinate *versus* urea) in one or two meals per day, Kozloski *et al.* (2009) note that intake of feed components and microbial protein entering into the small intestine was highest in animals offered calcium caseinate in two meals per day. Other authors, however, reported no effects of protein sources on intake, digestibility and rumen microbial protein synthesis (Kozloski *et al.*, 2007; Sawyer *et al.*, 2012).

Supplementing true protein and energy simultaneously to basal diets of ammoniated forages resulted in additive response in daily gain of ruminants (Royes *et al.*, 2001; Bodine and Purvis II, 2003; Nhiem *et al.*, 2013). Kozloski *et al.* (2007) noted that digestible energy intake, rumen microbial protein synthesis and nitrogen (N) retention were improved only when supplementation included both starch and protein, compared to supplementation with starch or protein separately. Microbial N flow to the duodenum increased as RDP level increased on the high ruminally degradable starch (RDS) diet, but was not affected by RDP level on the low RDS diet (Davies *et al.*, 2013). The evidence indicates that both duodenal flow of microbial N and microbial efficiency are greatest when diets are synchronized for

rapid rates of energy and protein degradation (Herrera-Saldana *et al.*, 1990; Aldrich *et al.*, 1993). Data from several studies summarized by Cruz Soto *et al.* (1994) showed that ruminal fermentation responded to RDP supplementation when dietary rumen fermentable carbohydrate (RFC) was increased, a response that can be attributed to a coupling of energy production with NH₃-N release that, consequently, increases the capture of NH₃-N for microbial protein synthesis. Microbial sequestration of ruminal NH₃-N during microbial protein synthesis is an energy-dependent process and is most efficient when energy and N availability are coupled (Reynolds and Kristensen, 2008).

Supplementation with increasing levels of CRM, enriched with 2.0 percent of urea, increased live weight gain (LWG) of growing Laisind cattle fed on elephant grass and rice straw (Ba *et al.*, 2008) and of sheep and goats fed on Napier grass diets (VanEys *et al.*, 1987). Increased CRM amounts in diets with protein source improved LWG of growing Laisind cattle (Thang *et al.*, 2010b).

Efficiency of protein utilization in the animal depends on energy supplementation (Schroeder and Titgemeyer, 2008). Moreover, the improvement on efficiency of protein utilization (EPU) because of protein is only possible because some energy is already available in the metabolism (Detmann *et al.*, 2014).

1.3 Fattening beef cattle

The effect of variable growth patterns on carcass fatness and conformation are influenced by several factors such as length and severity of the different feeding phases, and genetic background and maturity of the cattle.

1.3.1 Previous growth rate affect carcass characteristics, feed efficiency utilization

Finishing feeding prior to slaughter improved carcass, and meat quality of cattle (Minchin *et al.*, 2010). Supplementation during drought seasons increased LWG of cattle. However, cost on feed may limit such supplementation by many farmers. Cattle received concentrate supplementation during winter feeding period had warm carcass weight (WCW) and dressing percentage higher than those fed on the diet without supplementation (Blanco *et al.*, 2012). Animal performance during the winter period clearly impacts finishing LWG, carcass quality and beef production when cattle were finished to an equal-time endpoint (Neel *et al.*, 2007). Hesse *et al.* (2007) and Keane and Drennan (2009) reported that the winter diet affected carcass weight but not dressing percentage.

McCurdy *et al.* (2010) noted that feeding of a high-concentrate diet during the growing period may result in higher LWG, increased retained energy (RE) in the empty body and carcass, and greater efficiency of ME use to achieve similar carcass quality as compared with forage-based growing programs even at similar calculated ME intake.

The high body weight gains of compensatory animals result from several processes: an increased efficiency of energy use; reduced basal energy needs, and changes in circulating concentrations of metabolic hormones. It is estimated that 70-75% of energy consumed by cattle is used solely for body maintenance (Ferrell and Jenkins, 1984). Restricted feeding following re-feeding lambs caused more efficiency of performance which was associated with lower maintenance requirements due to lower weights of visceral organs (Shadnough *et al.*, 2011). Improvements in efficiency after realimentation have been attributed to a reduced visceral organ mass, and a resultant lowering of maintenance energy requirements (Fluharty and McClure, 1997). Reductions in metabolic rates and increased diet digestibility (Hornick *et al.*, 2000) relative to control animals fed *ad libitum*, with no prior feed restriction. Adding to catch-up growth, Sainz *et al.* (1995) reported that increased intake of feed DM accounted for 60 to 104% of the increased growth rate during finishing of previously restricted steers. However, maintenance energy requirements during finishing were increased for nutritionally restricted steers compared to those that have had higher nutritional levels during the previous phase (Hersom *et al.*, 2004).

Steers that were limit-fed concentrate in the growing phases were the most efficient in the finishing phase compared to those fed on *ad libitum* concentrate, *ad libitum* forage, and normal-weaned (Schoonmaker *et al.*, 2004). Rossi *et al.* (2001) also observed that feed efficiency was improved after periods of restriction in limit-fed cattle. In contrast, Schoonmaker *et al.* (2003) demonstrated that early-weaned cattle were not more efficient after periods of restriction compared to early weaned cattle that were not restricted.

1.3.2 Previous growth rate impact meat quality

Increased fatness increases feeding costs, because fat accumulation requires more energy compared to muscular tissue. In addition, excessive fat accumulation decreases the efficiency of feed utilization (Murphy and Loerch, 1994). By using partially restricted growth during the growing period it is possible to produce lower-fat and increased conformation carcasses (Carstens *et al.*, 1991). On the other hand increased carcass fatness may have positive effects on the eating quality of meat because fat accumulation may improve taste, tenderness and succulence of beef (Lawrie and Ledward, 2006).

Generally, accumulation of external fat is a prerequisite to accumulation of intramuscular fat (IMF). Marbling is the last fat depot to mature in the growing beef animal (McPhee *et al.*, 2008). Intramuscular adipocytes preferentially use glucose as a substrate for fatty acid synthesis, whereas subcutaneous fat uses acetate (Smith and Crouse, 1984). Glucose availability in ruminants is largely driven by the intake of metabolizable energy (ME) with higher ME intake promoting greater rates of gluconeogenesis (Lindsay, 1970). Rhoades *et al.* (2007) observed that high-starch diets enhanced glucose availability and uptake as well as IMF fatty acid synthesis; whereas animals fed high-forage diets have decreased glucose availability without changes in acetate incorporation into fatty acids. Vasconcelos *et al.* (2009) also reported that high-corn diets increased growing phase accretion of IMF and subcutaneous fat (SCF) regardless of level of energy consumption; and no difference in IMF was found in finished cattle when they were on the same finishing diet.

Several studies have found conflicting results when attempting to alter volatile fatty acids (VFA) patterns to increase IMF development. Bumpus (2006) found that steers fed a corn-based supplement had similar ultrasound IMF compared to steers fed a soyhullbased supplement. McCurdy *et al.* (2010) reported that steers limit-fed a corn-based diet had similar marbling scores compared to those fed a corn-silage based diet. In contrast, Faulkner *et al.* (1994) found that a corn-based creep feed increased IMF compared to a soy hull based creep feed. Sainz *et al.* (1995) found that steers limit-fed a corn-based diet had greater marbling scores than those fed an alfalfa hay-based diet.

Bruns *et al.* (2004) observed that marbling score and backfat increased as WCW increased during the feeding period. Nhiem (2012) reported that increasing slaughter weight partly resulted in increased IMF contents. Reduced growth rate during backgrounding tends to be associated with a reduction in the IMF contents of steers, despite the steers exhibiting compensatory growth during finishing (Pethick *et al.*, 2004).

Management practices in the growing phase can influence intramuscular fat deposition (Anderson and Gleghorn, 2007). However, previous studies (Hersom *et al.*, 2004; McCurdy *et al.*, 2010; Sharman *et al.*, 2013) have reported that nutrition and management practices prior to finishing had minimal effects on final marbling score when slaughtered at similar backfat thickness. Steers fed a high-concentrate diet *ad libitum* in the growing phase had the lowest percentage of fat and the highest percentage of moisture in the longissimus muscle at slaughter (Schoonmaker *et al.*, 2004). This is in contrast to the results of Schoonmaker *et al.* (2003), where source of energy and rate of gain did not affect longissimus muscle composition.

Muscle consists of three protein fractions, myofibrillar (salt-soluble), connective tissue (acid soluble), and sarcoplasmic (water-soluble) proteins. Myofibrillar proteins are the major protein fraction of skeletal muscle (Koochmaraie *et al.*, 2002). The turnover of myofibrillar protein occur at the surface of the myofibrils and the first step is probably disassembly of myofibrils into myofilaments (Goll *et al.*, 1992). This may or may not be a rate-limiting step. These myofilaments are subsequently degraded to polypeptides and ultimately to free amino acids. Dahlmann *et al.* (1986) observed that treatment that enhances myofibrillar protein turnover increases the fraction of easily released myofilaments (ERM), a small amount of myofilaments that constituted less than 5% of the total myofibrillar proteins and was easily removed (Etlinger *et al.*, 1975).

Vestergaard *et al.* (2000) examined the influence of different feeding strategies on meat from bull calves and found that longissimus dorsi was more tender when the young bulls had been fed *ad libitum* than when they were fed restrictively or compensatorily. During compensatory growth both the rate of protein synthesis and degradation are elevated in cattle (Jones *et al.*, 1990). Andersen *et al.* (2005) noted that both muscle protein degradation and synthesis reach a maximum level in bull calves exhibiting compensatory growth that exceeds the level found in continuously *ad libitum* fed calves. Therkildsen (2005) also reported that muscle protein turnover is affected by a restriction/re-alimentation feeding strategy, and that muscle protein degradation reaches a maximum during the re-alimentation period, which exceeds that of control animals (fed *ad libitum*). High protein degradation at slaughter will continue postmortem and affect meat tenderness in a positive way (Therkildsen and Oksbjerg, 2009).

AIMS OF THE THESIS

The overall aims of this study was to evaluate feeding strategies for improving quantity and quality of carcass and meat produced from Laisind cattle in Vietnam. The specific aims of the studies were:

Aim 1. To evaluate nutritive values of selected forages used in smallholder farms in the northern Vietnam (Paper I).

Aim 2. To examine the effects of supplementing varying levels of CRM without or with GNC to growing cattle fed on UTRST based diets (Paper II).

Aim 3. To examine the influence of supplementation regimes during growing phase on carcass characteristic and meat quality of finished cattle (Paper III).

MATERIALS AND METHODS

Study I was carried out to investigate DM intake and nutritive values of some selected forages used for ruminants in the northern Vietnam. Twenty forages which included 15 fresh forage (natural grass, maize stover, sweet potato vine, Stylo grass, elephant grass); 2 silages (maize stover and cassava tops) and 3 dried forages (Bermuda hay, natural grass hay, Guinea hay) were used in this study. Castrated rams of Phanrang breed (a local prolific sheep breed) with a live weight (LW) of 23-25 (\pm SD) kg were fed each forage *ad libitum* for 20 days, of which 10 days for data collection. The INRA system was used to calculate nutritive values of tested forages.

Study II was conducted using Twenty-four male cattle of crossbred Laisind (50% Red Sindhi and 50% local Yellow, both *Bos indicus*), from 15 to 17 months of age, 165-175 kg body weight, were used. They were assigned to a completely randomized block design in a 2 x 2 factorial arrangement (two CRM levels and two GNC levels). The two levels of CRM were 300g and 1000g; and without or with 700g GNC. The experiment lasted 98 days.

Study III was to be continued of the study II. After finished growing period in study II, all cattle were fed urea treated rice straw (URTRS) fed *ad libitum* and concentrate at 1.5 percentage of body weight (BW). The finishing period lasted for 105 days, including 14 days for adaptation. The concentrate fraction of the diet was gradually increased during a 2-wk period to achieve the 1.5% of BW. Then all animals were slaughtered for evaluating carcass characteristics and meat quality.

RESULTS AND DISCUSSION

Nutritive values and intake of some forages used for ruminants in the northern Vietnam

Chemical composition, feed intake and nutritive values

Overall, the forages used in the experiment had a crude protein (CP) concentration closely or higher than 80g/kg dry matter (DM) (Paper I), which are the required minimum to ensure the smooth function of the rumen microflora (Van Soest, 1994). The elephant grass, cultivated under the same location and management (harvested in October 2007), had a DM intake at 75 day's regrowth significantly higher than those at 45, 55 and 65 day of regrowth. Contradictory, advancing age of grass used for making silage reduced DM intake of Timothy/meadow fescue and tall fescue silages in sheep (Särkijärvi *et al.*, 2012). There was no difference in DM intake of elephant grass cutting at 4, 6 and 8 weeks of regrowth (Ngo and Wilkitorsson, 2003), or of dwarf elephant grass hay harvested at 30, 40, 50 and 60 days, and cut at 30, 50 70 and 90 days of growth (Kozloski *et al.*, 2003; Kozloski *et al.*, 2005). A low DM content of forage reduced DM intake (Pasha *et al.*, 1994). The digestibility of organic matter (OM), CP and crude fiber (CF) declined linearly with advance in maturity (Paper I). These results were in agreement with findings of Ngo and Wilkitorsson (2003) who involved elephant grass. The decreased forage digestibility with advancing maturity was due to decrease in leaf: stem ratio and a decline in quality of the stem fraction due to an increase in the proportion of cell wall, and its lignifications and increased proportion of the indigestible fractions (Van Soest, 1994; Mtengeti *et al.*, 1995; Wilman and Moghaddam, 1998). The advance of maturity will increase neutral detergent fiber (NDF) and acid detergent fiber (ADF) content of elephant grass, and reduce its *in situ* DM degradability (Silva *et al.*, 2008). The PDIN (protein truly digestible in the small intestine when N is the limiting factor), PDIE (protein truly digestible in the small intestine when energy is the limiting factor), ME (metabolizable energy) and UFV (net energy value for meat production) values of elephant grass were reduced as aging (Paper I). Our results are in line with Ngo and Wilkitorsson (2003), digestible energy reduced with longer cutting interval of elephant grass. Similarly, Abbasi *et al.* (2012) indicated that ME content will reduce with plant maturity. Forage quality depends on harvest date (Nordheim-Viken and Volden, 2009). Maturity is considered to be the primary factor affecting the chemical composition and nutritional quality of most forage (Nelson and Moser, 1994).

Elephant grass, with the same age of regrowth but from different locations and periods of harvesting, showed wide variations in DM and CP concentration, DM intake and digestibility of OM, CP, CF and nitrogen free extracts (NFE) (Paper I). These variations were due to

differences in managing and season of harvest. Seasons of harvest has influence on chemical composition of forage (Yayneshet *et al.*, 2009). Nitrogen fertilization have an profound effect on CP content of bermudagrass, bahiagrass and stargrass (Johnson *et al.*, 2001) and amaranth forage (Abbasi *et al.*, 2012). The DM intake of the elephant grass, except day 40 harvested in May 2007, were comparable to elephant grass intake harvested from humid tropics and the Mediterranean area (Xande *et al.*, 1989). The variation in nutritive value of elephant grass among seasons and years in this study was in consistent with Kozloski *et al.* (2005), who reported that age of regrowth was not a good indicator of nutritional value of elephant grass. The reduced protein value with advancing maturity of forage is consistent with the findings of Aumont *et al.* (1995). They also indicated that the low PDIE and PDIN value of tropical forage were due to low CP content. The protein, energy and net energy values of elephant grass in the current study were similar to those of elephant grass from humid tropics reported by Xande *et al.* (1989). The agronomic history of pasture (residual herbage after harvest), and its interactions with fertilization rate, type of soil, season and age of regrowth might change the leaf-to-stem ratio of tropical forages (Overman and Wilkinson, 1989).

The DM content of sweet potato vine (Paper I) was lower (15%) compared to results of earlier studies by Lam and Ledin (2004), Olorunnisomo (2007) and Katongole *et al.* (2008); who reported that the DM content were between 18 and 40%. In the present study, the CP concentration was 12%, comparable to results of Kariuka *et al.* (1998) and Katongole *et al.* (2008); 13.5% and ranging from 9.9 to 12.2%, respectively; but lower compared to Lam and Ledin (2004), Olorunnisomo (2007), ranging from 19.8 to 26.7%. The DM intake in the present study was lower than findings of Olorunnisomo (2007) where sweet potato foliage was sun-dried before feeding to sheep. The lower DM intake of the present study was probably due to high moisture content and a lower CP concentration. DM intake of sweet potato foliage was much lower compared to Napier grass and Lucerne (Kariuka *et al.*, 1998) when heifers were fed on these forages as sole feed. The OM and CP digestibility was high (75.9 and 67.6%, respectively) and was in accordance with previous studies (Olorunnisomo, 2007; Katongole *et al.*, 2008). The net energy values were high; 0.88 (UFL, net energy value for milk production) and 0.85 (UFV) (Paper I). The potential of sweet potato forage was discussed by Etela *et al.* (2008) who used the material to supplement Panicum grass in the diet of pre-weaned calves; DM intake of Panicum grass and of total diet, particularly live weight gain, were similar to supplementation with dried brewers' grains and cottonseed meal.

In the paper I, maize stover had DM intake and OM digestibility of 50.5 g/kg W^{0.75} and 63.0%, respectively; and net energy values of 0.73 (UFL) and 0.66 (UFV), comparable to

other maize stover. Andrieu *et al.* (1989) reported results of 33 trials that whole crop maize harvested at milk stage had DM intake around 52.0 g/kg $W^{0.75}$, OM digestibility of 72% and net energy values (0.90 and 0.84 for UFL and UFV, respectively) slightly higher than those in this study. The higher OM digestibility and nutritive values of this maize than those of this material is that grain was removed from maize forage in the current study. Maize stover silage has CP content (8.2%) (Paper I) similarly to results of Walsh *et al.* (2008), who reported CP concentration of 8.7%. Maize stover silage in the paper I had PDIN and PDIE values of 52 (PDIN) and 72g/kg DM (PDIE), ME and UFV values of 8.19 MJ, and 0.59 per kg DM; respectively. Walsh *et al.* (2008) indicated that when comparing maize stover silage (MS), whole-crop wheat harvested at a normal cutting height (WCW, stubble height 12 cm) or an elevated cutting height (HCW, stubble height 29 cm), whole-crop barley harvested at a normal cutting height (WCB, stubble height 13 cm) or an elevated cutting height (HCB, stubble height 30 cm) to fattening cattle; steers fed MS had a better feed conversion efficiency than those on WCW or WCB but were similar to HCW and HCB.

The CP contents (12.4% of DM) of Stylo grass (Paper I) was lower than results of Ba *et al.* (2013) who reported CP contents ranging from 14.7 to 17.9% of DM. In the paper I, the low DM intake (42 g/kg $W^{0.75}$) was in accordance with Stylo grass from dry area, wet season and 12 weeks of age in the humid tropics (Xande *et al.*, 1989). However, the OM digestibility of those was only 52% and their net energy values was lower than the present study. Stylo grass had 79 (PDIN), 80 g/kg DM (PDIE); ME and UFV values was 7.38 MJ, and 0.49 per kg DM, respectively (Paper I). As lambs fed urea treated rice straw (URTRS) and molasses, and supplemented with one of the four treatments: 1.5% concentrate, Stylo grass, cassava foliage, or Jackfruit foliage; Hue *et al.* (2010) found that the LWG was similar in all supplemented treatments. In another work, growing Laisind cattle fed a basal diet of URTRS, 0.87 kg concentrate and 0.22 kg molasses; and one of the following supplements (DM basis): 0.26 kg soybean meal (CON), 0.95 kg cassava foliage (CA), 1.01 kg Stylo foliage (STY), and mix of 0.49 kg Stylo foliage and 0.49 kg cassava foliage (CA-STY); the live weigh gain (LWG) of CA-STY have had higher than CA and was not significantly different with CON (Thang *et al.*, 2010a). In the paper I, fresh natural grass had CP concentration lower than that reported by Sanh *et al.* (2002). The DM intake of natural grass in the present study was 50.4 g/kg $W^{0.75}$. The PDIN and PDIE was 61 and 72 g/kg DM; respectively. The ME and UFV values was 8.36 MJ, and 0.61 per kg DM; respectively (Paper I). Its quality is variable and depends on many factors such as component of grass species, soil, seasons and etc. Obviously,

this natural grass was collected during the beginning of the dry season so its nutritive values could be lower compared to others.

Cassava tops silage had a CP content (14.6% of DM) lower than that reported by Man and Wiktorsson (2001) and Khang and Wiktorsson (2006); 21.1 and 20.3%, respectively. The current OM and CP digestibility was higher than those achieved in a previous study (Man and Wiktorsson, 2001), 52.1 and 45.8%. The stage of maturity, leaf-to-stem ratio, tannin concentration and fertilization may explain the difference in chemical composition and digestibility. In the paper I, DM intake of cassava top silage was 46.1 g/kg $W^{0.75}$. Cassava foliage contains tannin which decrease DM intake (Reed *et al.*, 1990) by reducing palatability and digestibility at high tannin levels (Kumar and D'Mello, 1995) when fed as sole feed, hence resulting in low values of ME and net energy (Paper I). Cassava tops silage had PDIN and PDIE value of 94 (PDIN), 79g/kg DM (PDIE), ME and UFV value was 6.92 MJ, and 0.46 per kg DM; respectively (Paper I). Growing heifers fed on URTRS basal diets supplemented with 100g CP from cassava tops silage/100 kg LW had higher LWG than those supplemented with 0.72 kg DM of Napier grass and 0.26 kg DM of CRM/100 kg LW (Khang and Wiktorsson, 2006).

Natural grass hay had DM intake of 62.8 g/kg $W^{0.75}$, 59 (PDIN) and 70 g/kg DM (PDIE), 7.35 MJ (ME) and 0.50 per kg DM (UFV) (Paper I). Nutritional values of this natural grass hay was similar to those reported by Richard *et al.* (1989). The DM intake of Bermuda hay was 63.2 g/kg $W^{0.75}$; PDIN and PDIE values was 45 and 71g/kg DM; ME and UFV values was 8.65 MJ, and 0.63 per kg DM; respectively (Paper I). The CP content and nutritive value of Bermuda grass hay (Paper I) was slightly lower than those reported in the previous study (Aumont *et al.*, 1995). The DM intake Guinea hay was 51.6 g/kg $W^{0.75}$; 94 (PDIN) and 89 g/kg DM (PDIE); ME and UFV value was 7.64 MJ, and 0.52 per kg DM; respectively (Paper I). The Guinea hay in the present study had CP concentration higher but lower DM and OM digestibility than Guinea grass hay cut at 35 days reported by Avellaneda *et al.* (2009).

Correlation among nutritional composition of elephant grass and its DM intake, digestibility

The correlation coefficients of some characteristics of elephant grass were showed in Paper I. Stage of maturity was positively correlated with DM concentration (correlation was 0.747, $P<0.05$) and negatively correlated with CP content (correlation was -0.626, $P<0.05$) as expected. DM intake (DMI) was positively correlated with DM and ADF concentration (correlations were 0.729 and 0.784, respectively; both $P<0.05$) (Paper I). The significant

positive correlation between DMI and DM contents ($P < 0.05$) of the elephant grass was probably due to the low DM contents of the forage. Previous studies showed a restriction in DM intake if the DM content is low (Lahr *et al.*, 1983; Pasha *et al.*, 1994). The low DM content of fresh forages in this study because these forages were harvested in the summer/rainy seasons. Lippke (1980) reported highly negative correlation between DM intake and ADF, which was inconsistent with our results. This may have been due to the low ADF intake per kg metabolism weight of sheep in the present study. There was no significant correlation between DMI and NDF (Paper I), a result which was not expected. Because NDF generally ferments and passes from the reticulorumen more slowly than other dietary constituents, it has a greater filling effect over time than non-fibrous feed components and has been found to be the best single chemical predictor of voluntary DM intake (Allen, 1996).

Digestible protein and CP (Paper I) were related by a linear equation, showing the usual strong association (correlation was 0.88) and coefficient of true digestibility, 0.89. Those results coincides with findings of Lippke (1980).

Influence of varying levels of supplemental cassava root meal (CRM) without or with groundnut cake (GNC) on performance of growing Laisind cattle

The HCN intake of cattle in the current experiment was much lower than the toxic dose reported by Majak (1992), who indicated that 2 mg/kg BW is consider to be lethal for ruminants. A CRM by GNC interaction for URTRS intake was found, such as increasing levels of CRM supplementation decreased URTRS intake in the absence of GNC while there was no difference in the GNC diets (Paper II). This observation was supported by previous results, increasing amounts of CRM resulted in linear reduction of forage intake in growing cattle (Wanapat and Khampa, 2007; Ba *et al.*, 2008) and sheep (Kozloski *et al.*, 2006). Reduction in forage intake is primarily caused by reduced NDF digestion (Dixon and Stockdale, 1999). There was an interaction between CRM and GNC on total DM intake (Paper II). Total DM intake increased as higher CRM level supplementation in the GNC diets but no difference was found in the diets without GNC. This interaction was due to improved intake of URTRS and supplements by supplementation of 1000g CRM compared to 300g CRM in the presence of GNC.

Live weight change and feed conversion ratio (FCR)

Cattle offered 1000g CRM achieved a greater LWG than those offered 300g CRM on the GNC diets, but with the diets without GNC, no difference were detected between CRM levels (interaction, Paper II). This interaction was attributed to either increased digestible OM intake (DOMI), and/or improved efficiency of protein utilization (EPU) in both ruminal fermentation and metabolic protein status of cattle fed 1000g CRM compared to 300g CRM on the GNC diets. The increased DOMI would provide a greater supply of energy and synthesis of ruminal microbial to the host animals. The higher dietary starch level enhanced microbial N flow to the duodenum and microbial efficiency as compared with those on low starch level at the high RDP diet (Davies *et al.*, 2013). The CP intake of cattle offered 1000g CRM was not significantly different to those offered 300g CRM; the former had much higher LWG (49%) compared to those of the latter (Paper II). In line with this, Thang *et al.* (2010b) noted that growing Laisind cattle given diets having the same CP intake, the LWG of cattle offered high ME diet was 53% higher than those given the lower ME diet. Animals did not respond or responded with a very low efficiency to the additional protein supply when energy intake was a limiting factor (Schroeder and Titgemeyer, 2008). Furthermore, the improvement on EPU because of protein is only possible because some energy is already available in the metabolism (Detmann *et al.*, 2014). Such improvements in EPU together with increased DOMI are thought to contribute to enhanced growth performance of cattle offered 1000g CRM with 700g GNC. Improvements in LWG and FCR by supplementation of both energy and protein to cattle fed forage based diets were additive to response from supplementation with energy or protein individually (Bodine and Purvis II, 2003; Nhiem *et al.*, 2013). Their findings were similar to the current results when supplementing GNC to 1000g CRM, but was not the case as GNC addition to 300g CRM. This inconsistent response has been due to differences in sources and quantity of supplemental protein and energy, leading to different effects on forage intake between treatments and among trials. In the absence of GNC, supplementing 1000g CRM failed to improve LWG compared to 300g CRM, which was partly due to substitution of supplements for URTRS. The present experiment demonstrates the importance of both sufficient amounts of CRM and GNC supplementation of URTRS to achieve a desired level of performance.

A CRM by GNC interaction for feed cost was also found in the Paper II. This interaction might be of important practical implications for livestock producers or farmers when supplementation to a URTRS-based diet of growing cattle. Additions of 1000g CRM was not

an economic benefit compared to 300g CRM given alone. Supplementing both 1000g CRM and 700g GNC resulted in 24% lower (28,000 versus 37,000 VND/kg LWG) total expenditure for feed per kilogram LWG compared to supplementation of only 300g CRM.

The coefficient of digestibility

Higher levels of CRM resulted in cattle having significantly higher OM and CP digestibility compared to those offered low levels of CRM (Paper II). Similarly, increasing supplemental CRM resulted in increasing OM (Thang *et al.*, 2010b) and CP digestibility (Kozloski *et al.*, 2006; Ba *et al.*, 2008). Supplementation of GNC resulted in significantly higher digestibility of OM and CP compared to those offered non GNC (Paper II). The current findings in Paper II were in agreement with previous authors (Bodine and Purvis II, 2003; Nhiem *et al.*, 2013) supplementing true protein increased digestibility of OM and CP.

Digestibility of NDF (interaction) decreased as CRM level increased on the diets without GNC, but was not affected on the diets with GNC (Paper II). This was probably attributed to increasing starch in the diet causes enhancing the lag phase before the initial of fiber digestion (Huhtanen *et al.*, 2008) and a decrease in the rate of NDF digestion (Souza *et al.*, 2010). In addition, CRM has high starch content (Mejía-Agüero *et al.*, 2012) and is extensively and rapidly fermented in the rumen (Chanjula *et al.*, 2003). Thus at high intake this could have led to a subacute rumen acidosis, which suppress cellulolytic activity. Kozloski *et al.* (2006) observed a linear decrease in NDF digestibility with increasing CRM supplement at 5, 10 and 15g/kg LW of lambs even when nitrogen was not limiting for rumen bacteria. Ba *et al.* (2008) showed that NDF digestibility decreased linearly when growing Laisind cattle were fed with increasing levels of CRM, ranging from 0.3 to 2.0% of BW.

Varying supplemental cassava root meal without or with groundnut cake during growing phase impacts performance, carcass and meat quality of finished Laisind cattle.

Different supplemental strategies result in different LWG during growing phase had no effect on intake of URTRS, total-diet DM, ME and CP during the finishing phase (Paper III). The present findings agree with results of Loken *et al.* (2009) who indicated that feeding steers that differ in energy concentration in the growing period had similar DM intake during finishing phase. These results were due to live weight of cattle was not large difference enough and there were no restricted feeding cattle during the growth period.

Protein levels of supplement during growing phase had a carry-over effect on LWG of finishing cattle such as cattle offered the non GNC diet had a significantly higher LWG compared to those offered GNC (Paper III). Similarly, cattle supplemented with high protein pellets during growing phase had lower LWG in the fattening period (Robinson *et al.*, 2001). Schoonmaker *et al.* (2004) showed that lower growth rate during growing phase gave higher LWG during finishing period compared to those having high LWG during growing phase. Neel *et al.* (2007) reported that cattle fed to achieve a low daily gain during winter had the greatest LWG during the finishing period, whereas cattle fed to achieve a high daily gain had the lowest LWG during the finishing period. There were no carry-over effects of CRM supplementation in the growing phase on LWG in the finishing period (Paper III). Loken *et al.* (2009) observed that feeding steers diets that differ in energy concentration and result in LWG of 1.4 and 1.7 kg/d during the growing period had no difference in LWG during finishing phase.

Supplementing 700g GNC resulted in cattle having higher FCR_{DM} compared to those offered without GNC (Paper III). Increased feed intakes and better feed conversion were found for finishing steers backgrounded on a low energy hay diet when compared with finishing cattle fed a high-energy diet during the growing phase (Merchen *et al.*, 1987). Cattle offered 1000g CRM during the growing period had a significant higher feed conversion ratio (FCR_{DM}) compared to those offered 300g CRM (Paper III). McGregor *et al.* (2012) showed that no improvement in FCR_{DM} was observed for fattened steers that were limit-fed grain or backgrounded on alfalfa haylage compared to those fed ad libitum grain during backgrounding.

There was significant interaction between supplemental CRM and GNC during growing phase on warm carcass weight (Paper III) such as higher CRM increased warm carcass weight compared to lower CRM level on the GNC diets. Blanco *et al.* (2012) reported that even the finishing weight was not significant different between supplemented and unsupplemented cattle, the cattle supplemented with concentrate during winter period had higher warm carcass weight and dressing percent compared to those fed on unsupplemented diets during winter. Keane and Drennan (2009) showed that the winter diet increased carcass weight but not dressing percentage. Dressing percent of finishing Laisind cattle in the current study was higher than those achieved in finished Laisind cattle in a previous study (Nhiem, 2012), who reported that finished Laisind cattle had dressing percent of 48.33. This difference may be due to the final live weight in the present study which were ranging from 303 to 315kg compared to around 274kg in the experiment by Nhiem (2012). Vestergaard *et al.* (2007)

showed that fattened cattle having higher live weight at slaughter had higher dressing percent compared to those having lower live weight. Edible meat of cattle supplemented high CRM and GNC had higher than those fed on high CMR without GNC during growing period (Paper III); this was attributed to difference in carcass weight. There was a carry-over effect of level of both CRM as well as GNC on the fat contents (trimmed fat) of carcass (Paper III). Finished cattle supplemented with high CRM level during growing phase had higher trimmed fat compared to those fed on low CRM level in the Paper III. Supplementation of GNC during growing period resulted in cattle having higher trimmed fat compared the cattle fed on without GNC diets (Paper 3). Therkildsen *et al.* (1998) observed that cattle having higher LWG during growing phase had higher fat cover (EUROP fatness) compared to those were low LWG. Another reason could be due to increased warm carcass weight resulted in increased trimmed fat, which is consistence with previous results of Nhiem (2012) in Laisind cattle. The higher trimmed fat in the present study partly explained the lower FCR_{ME} for increasing LWG.

Meat color values in the study were comparable to values of Laisind meat produced in Vietnam (Hue *et al.*, 2008; Luc *et al.*, 2009; Nhiem, 2012). There was no difference in L^* value (lightness) and a^* value (redness) between groups in the Paper III, which is in agreement with McGregor *et al.* (2012) who noted previous feeding regimes had no effects on color values of finishing cattle. There was no carry-over effect of supplemental regimes during growing period on the shear force value (Paper III). The present results was slightly lower than those reported by Nhiem (2012) in Laisind cattle slaughtered at a lower weight (270 kg). Vestergaard *et al.* (2000) reported that difference in LWG during growing phase had no effects on the shear force value of finished cattle.

Supplementation with the higher level of CRM or GNC during the growing phase increased lipid concentration (intramuscular fat) of finished cattle (Paper III). This could be due to difference in growth rate during the growing phase and/or different slaughter weight. Steers with better nutrition during growing phase tended to have more intramuscular fat (IMF) contents compared to those on lower nutrition after fattening (Robinson *et al.*, 2001). Vestergaard *et al.* (2000) noted that IMF content of *m. longissimus dorsi* was higher when the young bulls had been fed *ad libitum* than when they were fed restrictively or compensatorily. Reduced growth rate during backgrounding tends to be associated with a reduction in the IMF contents of steers, despite the steers exhibiting compensatory growth during finishing (Pethick *et al.*, 2004). Nhiem (2012) reported that increasing slaughter weight partly resulted in increased lipid contents. Marbling scores increased linearly with warm carcass weight (Bruns *et al.*, 2004). However, slaughter weight had no effects on IMF content of crossbred Brahman and Charolais with Thai native cattle (Waritthitham *et al.*, 2010). Sharman *et al.* (2013; Exp. 2) indicated that marbling score increased as slaughter weight increased after growing phase, and there was no difference in marbling score after finishing.

CONCLUSION AND FURTHER PERSPECTIVES

The present study has shown that digestibility, PDIN, PDIE, ME and UFV values of elephant grass cultivated under the same location and management reduced as aging, but DM intake of grass cutting at 75 days was highest. Elephant grass, harvested at the same age of regrowth but from different locations and periods of time, showed wide variations in DM, CP contents, DM intake and digestibility as well as PDIN, PDIE, ME and UFV values. The DM intake of natural grass was 50.4 g/kg $W^{0.75}$. The PDIN and PDIE was 61 and 72 g/kg DM; respectively. The ME and UFV values was 8.36 MJ/kg DM, and 0.61 per kg DM; respectively. Sweet potato vine had low DM content and DM intake (35.2 g/kg $W^{0.75}$), but the net energy values were high; 0.88 and 0.85 for UFL and UFV. Maize stover had DM intake of 50.5 g/kg $W^{0.75}$, and net energy values of 0.73 (UFL) and 0.66 (UFV). Maize stover silage had PDIN and PDIE values of 52 and 72, ME and UFV values of 8.19 MJ/kg DM and 0.59 per kg DM; respectively. Stylo grass had 79 (PDIN), 80g/kg DM (PDIE); ME and UFV values was 7.38 MJ/kg DM, and 0.49 per kg DM, respectively. Cassava tops silage had DM intake of 46.1 g/kg $W^{0.75}$ and its PDIN and PDIE values was 94 (PDIN), 79g/kg DM (PDIE), ME and UFV values was 6.92 MJ/kg DM, and 0.46 per kg DM; respectively. Natural grass hay had DM intake of 62.8 g/kg $W^{0.75}$, PDIN (59) and PDIE (70g/kg DM), ME (7.35 MJ/kg DM) and UFV (0.50). The DM intake of Bermuda hay was 63.2 g/kg $W^{0.75}$; PDIN and PDIE values was 45 and 71g/kg DM; ME and UFV values was 8.65 MJ/kg DM, and 0.63; respectively. The DM intake Guinea hay was 51.6 g/kg $W^{0.75}$; 94 (PDIN) and 89g/kg DM (PDIE); ME and UFV values was 7.64 MJ/kg DM, and 0.52; respectively.

There was a reduced URTRS intake and no improved LWG when growing Laisind cattle were supplemented with 1000g compared to 300g CRM in the diets without GNC. The combination of 1000g CRM and 700g GNC significantly increased LWG, and tended to improve URTRS intake and OM digestibility, reducing the FCR and feed cost.

Varying supplementation strategies during growing phase affect subsequent growth rate, efficiency of feed utilization, carcass weight, edible meat and intramuscular fat. Cattle offered 1000g CRM and 700g GNC during growing phase had highest carcass weight, edible meat, trimmed fat and intramuscular fat contents compared to the rest.

Interesting direction for future work includes compare the performance of cattle fed on different forages. For growing cattle, a comparison between protein sources (urea and true protein) and with larger difference in CRM levels need to be tested. The difference in supplementation strategies results in different LWG during the growing phase was not large

enough leading to difference in carcass and meat quality. Furthermore, there was no reduced LWG in this study because most householder farmers keep only few cattle so that they look after their animals well. However, there are some large farms and the inadequate of ruminant feed during drought seasons occur frequently therefore more different feeding strategies before entering finishing period also should be examined. In practical conditions, many farms finish their cattle by using around 2.0-3.0 kg of concentrate and achieve LWG of around 0.5kg/day for around 2-3 months before selling to markets. Thus, using the best growing cattle diet used in this study and other finishing diets containing high concentrate levels to fatten cattle until reach the same finished body (live) weight, and then compare these finished in term of performance, carcass, meat quality and economic benefit.

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Paper I

Nutritive values of selected forages used by traditional small farms in the northern Vietnam

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Abstract

The objective of the experiment was to investigate nutritive values and dry matter (DM) intake of some forages used for ruminants in the northern Vietnam. Twenty forages which included 15 fresh forages: natural grass, maize (*Zea mays* L.) stover, sweet potato (*Ipomoea batatas*) vine, Stylo grass (*Stylosanthes guainensis* CIAT 184), elephant grass (*Pennisetum purpureum*); 2 silages: maize (*Zea mays* L.) stover, and cassava (*Manihot esculenta*, Crantz) tops; and 3 dried forages: Bermuda (*Cynodon dactylon*) hay, natural grass hay, Guinea (*Panicum maximum* cv.TD58) hay were used in this study. Castrated rams of Phanrang breed (a local prolific sheep breed) with a live weight (LW) of 23-25 (\pm SD) kg were fed each forage *ad libitum* for 20 days, of which 10 days for data collection. The INRA system was used to calculate nutritive values of tested forages. The DM intake of fresh forages (except elephant grass) of natural grass and maize stover was highest (50.4 and 50.5 g/kg $W^{0.75}$; respectively), followed by stylo grass (40.2) and of sweet potato vine was lowest (35.4 g/kg $W^{0.75}$). The PDIN (protein truly digestible in the small intestine when nitrogen is the limiting factor) and PDIE (protein truly digestible in the small intestine when energy is the limiting factor) of natural grass, maize stover, sweet potato vine and stylo grass was 61, 71, 77 and 79 (PDIN), and 72, 80, 95 and 80g/kg DM (PDIE); respectively. The ME (metabolizable energy) and UFV (net energy value for meat production) values were 8.36, 8.90, 10.31 and 7.38 MJ/kg DM, and 0.61, 0.66, 0.85, and 0.49 per kg DM; respectively.

The DM intake of elephant grass harvest from different locations, years varied largely from 34.2 (40 days, May 2007) to 65.4 g/kg $W^{0.75}$ (60 days, September 2005). Their PDIN and PDIE was ranging from 57 (60 days, Sept 2005) to 105 (40 days, May 2005), and 75 (50 days, Aug. 2006) to 105 g/kg DM (40 days, May 2007); respectively. The ME and UFV value was ranging from 7.58 (50 days, Aug. 2006) to 9.72 MJ/kg DM (40 days, May 2005), and 0.55 (50 days, Aug. 2006) to 0.77 per kg DM (40 days, May 2005); respectively. Elephant grass, cultivated in the same management condition and harvested at 45, 55, 65 and 75 days of regrowth, had reduced its nutritive values as ages advancing, but DM intake at 75 days had higher than those harvested at 65, 55 and 45 days. The DM intake was 35.6, 38.4 36.5 and 43.0 g/kg $W^{0.75}$, PDIA (dietary protein undegraded in the rumen which is digestible in the intestine) values reduced from 37 to 26 g/kg DM; PDIN and PDIE reduced from 70 to 49, and 84 to 72 g/kg DM; respectively. Their ME and UFV values declined linearly from 8.95 to 8.52 MJ/kg DM and 0.75 to 0.70 per kg DM; respectively. Maize stover and cassava tops silage had DM intake of 53.3 and 46.1 g/kg $W^{0.75}$; respectively. Their PDIN and PDIE values was 52 and 94 (PDIN), 72 and 79g/kg DM (PDIE), ME and UFV values was 8.19 and 6.92 MJ/kg DM, and 0.59 and 0.46 per kg DM; respectively. The DM intake of Bermuda hay, natural grass hay and Guinea hay was 63.2, 62.8 and 51.6 g/kg $W^{0.75}$; respectively. Their PDIN and PDIE values was 45, 59 and 94 (PDIN), and 71, 70 and 89 (PDIE); ME and UFV values was 8.65, 7.35 and 7.64 MJ/kg DM, and 0.63, 0.50 and 0.52; respectively. In conclusion, sweet potato vine was potential forage if its DM intake could be overcome by wilting before feeding to animals. Natural grass, maize stover, Stylo grass and maize stove silage were good quality forage and their DM intakes were acceptable. There were variables in DM intake and nutritional values of regrowth elephant grass at the similar ages, harvesting from different locations and years. The advancing maturity of regrowth elephant grass cultivated under the same condition increased DM intake, but reduced nutritive values. Cassava tops silage should be used as a protein supplemental source instead of feeding as a sole feed. Bermuda hay, natural grass hay and Guinea hay has had medium quality but DM intake were good.

1. Introduction

In the northern Vietnam, feeding of ruminants is largely dependent on pasture grasses and crop production during rainy seasons. The increasing demand for crop land results in reduced grazing areas. Due to variation in quantity and quality, and overgrazing in low land areas, the use of natural grass is partly replaced by cultivated grass and crop by-products. There is a number of tropical grass, of which elephant grass (*Pennisetum purpureum*), also known as Napier grass, has received a lot of attention. Elephant grass is tropical grass with high yield and nutritional balance (Ferreira *et al.*, 2010). Stallholder farms therefore usually cultivate elephant grass to supply forages for ruminants. It is fed fresh and chopped to the animals. Elephant grass cut at six to eight weeks of regrowth give the best balance between forage yield and quality (Ngo and Wiktorsson, 2003). However, age of regrowth is not a good indicator of nutritional value of elephant grass (Kozloski *et al.*, 2005). Besides elephant grass, Stylo grass (*Stylosanthes guainensis* CIAT 184) is used in some areas. Locally available crop by-products are also used as alternative feedstuffs. Maize stover (*Zea mays* L.) is always collected after harvesting the young grain used for human food; a part is fed freshly and some of the material is ensilaged when abundant amount is available. Sweet potato (*Ipomoea batatas*) is the third most important crop after rice and maize (An *et al.*, 2005) and its vine is normally fed to pigs and to cattle without wilting before feeding. Cassava production was around 10 million tons in 2011 (GRO, 2013). Fresh cassava (*Manihot esculenta*, Crantz) foliage contains high levels of cyanogenic glucosides, which produce the cyanide (HCN) toxin. Cyanide content in cassava foliage can be reduced to levels that are safer for animals by ensiling (Man and Wiktorsson, 2001) or drying (Phuc *et al.*, 2000). Bermuda grass (*Cynodon dactylon*) hay, natural grass hay and guinea grass (*Panicum maximum* cv.TD58) hay are also used for ruminants.

The voluntary feed intake and the efficiency of extraction of nutrients from the feed during digestion are the most important determinants of nutritive value of a feed. *In vivo* digestion is the most accurate method to measure the apparent digestibility of feedstuffs and dry matter intake. To the authors' knowledge, little results of *in vivo* research to evaluate the nutritive value of forages used by ruminants in the northern Vietnam have been published. Nutritive values of forage vary largely and depend on many factors such as species, maturity, soil fertility, fertilizer application, and seasons as well. Knowledge of the variation of feed quality that exists is important in formulating feeding systems and explaining variation in livestock production to different strategies.

The equations used in nutritive value determination of experimental feedstuffs according to the INRA system has been used in Vietnam for more than ten years and the available database has been fitted to these equations (Vu *et al.*, 2011). Therefore, the objectives of this study were to estimate nutritive values of selected forages for ruminants according to the INRA system.

2. Materials and methods

2.1. Sampling sites and the study areas

All samples were collected in the northern Vietnam during 2005, 2006 and 2007. A total of 20 forages, which included 15 fresh forages (natural grass, maize stover, sweet potato vine, Stylo grass, elephant grass), two silages (maize stover and cassava tops) and three dried forages (Bermuda hay, natural grass hay, Guinea hay) were used in this study. The natural grass was collected in the commune field around Hanoi during October 2005. The maize stover was harvested after collecting the young grain (in the milk stage) in December 2006. The sweet potato was a local variety, collected in October 2006 in villages in Dong Anh district, Hanoi. Stylo grass was collected at 30 days of regrowth during July 2006. The elephant grasses were regrowth and harvested at different stage in 2005, 2006 and 2007. The elephant grass was cut 10cm above the ground. The elephant grass collected during October 2007 was harvested from the same soil style and fertilization. The maize stover silage was made from maize stover without ear corn (in the milk stage). Bermuda hay and natural grass hay were harvested in 2005, and Guinea hay was collected during 2006.

2.2. In vivo digestibility trial

The *in vivo* trials were conducted at the Experimental Station of the National Institute of Animal Sciences, Thuyphuong, Tuliem, Hanoi, Vietnam over three consecutive years (2005, 2006 and 2007). For the trials, castrated rams of Phanrang breed (a local prolific sheep breed) with a live weight (LW) of 23-25 kg were used. The rams were kept in a confined regime, housed in an individual metabolism cages supplied with an individual feeder and drinker. Each trial lasted 20 days, with 10 days for diet adaptation and 10 days for total feces collection. Each feedstuff was fed to five sheep. The trial for elephant grass collected during Oct 2009 was designed as a randomized block with 4 treatments and 5 replications.

All measurements were made using sheep fed *ad libitum* (with 20% refusals) in order to measure the voluntary intake and digestibility at the same time. The used level was chosen because Demarquilly and Adrieu (1987) reported that digestibility measured on animals fed

ad libitum was only slightly lower 1.6 units (%) in the 17 comparisons made than that measured on animals with restricted feeding. All animals had free access to clean water and a mineral block containing 90g Ca, 90g P, 150g Na, 5g Mg, 10g Fe, 6000mg Mn, 800mg Cu, 400mg C0, 50mg I and 100mg Se per 1 kg block; yet no supplement was provided.

The forages were chopped by hand into slices of 3-5 cm before feeding. Maize stover and cassava tops were also chopped before ensilaging. All feed offered for the 10-d fecal collection period was weighed and sampled daily. Feed refusals were also weighed, sampled daily and the DM of the refusal was determined. Daily fecal output was measured by total collection into individual trays placed underneath the metabolism cages. The daily fecal collection for each sheep was mixed, and a 5% aliquot sample was taken and kept in a freezer at -18°C. At the end of the collection period, samples of feeds, refusals and feces were thawed, bulked, mixed and a sub-sample was taken for each sheep.

2.3. Chemical analysis

Samples of feeds and feces were ground (1-mm screen) and dried at 55°C until it reached a constant weight for the determination of dry matter (DM) content of ash was determined by bomb calorimeter (muffle furnace at 550°C for 4 h), crude protein (CP, % nitrogen (N) x 6.25) was determined by Kjeldahl technique (AOAC official method 954.01, AOAC (1997)), crude fiber (CF) (AOAC official method 978.10, AOAC (1997)), ether extract (AOAC official method 920.39, AOAC (1997)), neutral detergent fiber (NDF) and acid detergent fiber (ADF) (Van Soest *et al.*, 1991).

2.4. INRA predictive equations

The gross energy (GE) was determined according to the equation fitted by Xande *et al.* (1989) on tropical forage from Guadeloupe and Cuba (Table 1). The value of energy digestibility (dE) was calculated for each sample from a value of predicted *in vivo* OMD of the grass (Xande *et al.*, 1989). The other factors of the following equations can be calculated from chemical components (OM, CP, EE and CF) according to the INRA energy and protein evaluation system (Demarquilly *et al.*, 1989; Vermorel, 1989; Xande *et al.*, 1989) (Table 1). The net energy (NE) of the forages was calculated from its gross energy (GE) content, dE, the ratio of metabolizable energy (ME) to digestible energy (DE), and the overall efficiency of ME utilization (k) for production (kl, lactation; kmf, meat production), according to the equation: $NE = GE \times dE \times (ME/DE) \times k$ (Vermorel, 1989).

The protein values of grass are expressed in terms of protein truly digestible in the small intestine (PDI), and are the sum of the dietary protein undegraded in the rumen which is digestible in the intestine (PDIA) and the microbial true protein truly digestible in the small intestine (PDIM). Each feed contributes to microbial synthesis through both the degradable N and the available energy it supplies to the rumen microorganisms (INRA, 1989). Thus, each feedstuff is characterized by two PDIM values: (i) PDIMN, which corresponds to the amount of microbial protein that could be synthesized from the degraded dietary N when energy is not limiting; and (ii) PDIME, which is the amount of microbial protein that could be synthesized from the energy available in the rumen when degraded N is not limiting. The undegraded nitrogen in the rumen is estimated from nitrogen degradability (ND) assessed by *in sacco* method according to Orskov and McDonald (1970). The ND of tropical forages was fixed at 53% (Aumont *et al.*, 1995). The amino acid contents (AAC) of microbial protein and rumen-undegraded dietary protein were fixed to 800 g/kg and the related digestibility (AAD) to 80% according to Vérité *et al.* (1987). In order to get a comprehensive view of the feed value and to make calculations of diet easier, the value of each feed was given directly as the sum of PDIA and PDIM, considering separately each of the two possible situations: (i) $PDIN = PDIA + PDIMN$ and (ii) $PDIE = PDIA + PDIME$. Thus a particular feature system was that it assigns two protein values to each feed: PDIN and PDIE. The lower of these two values was the real value of the feed when it was fed solely (Vérité and Peyraud, 1989).

Table 1. Equations used in nutritive value determination in the INRA system unit of some forages in the northern Vietnam

No.	Equation	Reference
1	$GE \text{ (g/kg OM)} = 4543 + 2.0113 \times CP \text{ (g/kg OM)}$	Xande <i>et al.</i> (1989)
2	$dE \text{ (\%)} = 0.983 \text{ OMD} - 0.03$	Xande <i>et al.</i> (1989)
3	$FOM = DOM - EE - CP \text{ (1-ND} \times 0.01)$	Vérité <i>et al.</i> (1987)
4	$DE = GE \times dE/100$	Demarquilly <i>et al.</i> (1989)
5	$ME/DE \text{ (g/kg OM)} = 0.8417 - [9.9 \times 10^{-5} CF \text{ (g/kg OM)}] - [1.96 \times 10^{-4} CP \text{ (g/kg OM)}] + 0.0221 \times L$	Vermorel (1989)
6	$ME = DE \times (ME/DE)$	Vermorel (1989)
7	$kl = 0.463 + 0.24 (ME/GE); kmf = [0.3358 (ME/GE)^2 + 0.6508 (ME/GE) + 0.005]/(0.9235 (ME/GE) + 0.2830)$	Vermorel (1989)
8	$UFL = ME \times kl/1700$	Vermorel (1989)
9	$UFV = ME \times kmf/1820$	Vermorel (1989)
10	$PDIA = 1.11 CP \text{ (1 - ND)} AAD \times AAC \times 10^{-5}$	Vérité <i>et al.</i> (1987)
11	$PDIMN = CP \text{ (1-[1.1(1-ND)])} AAD \times AAC \times 10^{-5}$	Vérité <i>et al.</i> (1987)
12	$PDIME = FOM \times 0.145^a \times AAD \times AAC \times 10^{-5}$	Vérité <i>et al.</i> (1987)
13	$PDIN = PDIA + PDIMN; PDIE = PDIA + PDIME$	Vérité and Peyraud (1989)

Chemical composition (g/kg OM for equation 1 and 5; g/kg DM for equation 3 and 10). *FOM* fermentable organic matter; *DOM* digestible organic matter; *EE* ether extract; *CP* crude protein; *CF* crude fiber; *L* = 1 at maintenance; *kl* the efficiency of ME utilization for lactation; *kmf* the overall efficiency of ME utilization for meat production; *UFL* net energy of feed stuff for milk production; *UFV* net energy of feed stuff for meat production; *PDIA* the dietary protein undegraded in the rumen which is digestible in the intestine; *PDIMN* which corresponds to the amount of microbial protein that could be synthesized from the degraded dietary nitrogen (N) when energy is not limiting; *PDIME* which is the amount of microbial protein that could be synthesized from the energy available in the rumen when degraded N is not limiting. *ND* nitrogen degradability in the rumen, the ND of tropical forages was fixed at 53% (Aumont *et al.*, 1995). *AAC* Amino acid content of microbial protein or in protein supplied by rumen-undegraded dietary protein, fixed at 800 g/kg DM. *AAD* digestibility of amino acid, fixed at 80.0 percentage units (Vérité *et al.*, 1987)

^a This coefficient is related to efficiency of organic matter (OM) fermentation in microbial protein (g/kg DM) (Vérité *et al.*, 1987).

2.5. Statistical analysis

The variation between cutting date of elephant grass within the individual year was analyzed by one-way analysis of variance in Minitab (2004) using the model:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_j$$

Where Y_{ij} is the observed dependent variable, μ is the overall mean, α_i is the effect of the cutting date, ε_j is the residual error. Mean value were considered different at a p-value ≤ 0.05 . The correlation coefficient between the some characteristics and significant test were also calculated according to Pearson's linear correlation coefficient. Best subsets regression identifies were used to identify models for estimation of dry matter intake (DMI), organic matter digestibility (OMD) and digestible crude protein (DCP).

3. Results and discussion

3.1. Chemical composition, feed intake and nutritive values

The chemical compositions of forages are shown in Table 2 and Table 3 presents the apparent digestibility. Generally, all forages had CP content closely or higher than 80g/kg DM, which are the required minimum to ensure the smooth function of the rumen microflora (Van Soest, 1994). In elephant grass from different growth stages harvested in October 2007, the DM intake from day 75 was significantly higher than those from day 45, 55 and 65 ($P < 0.05$). This result was inconsistent with Särkijärvi *et al.* (2012), sheep reduced DM intake of Timothy/meadow fescue and tall fescue silages with a delay in harvest of grass used for making silage. The increase in DM intake as advance in regrowth in the current study may be due to the low DM content of grass harvesting from day 45, 55 and 65. Ngo and Wilkitorsson (2003) reported no difference in DM intake of elephant grass cutting at 4, 6 and 8 weeks of regrowth. The DM intake of elephant grass day 75 was in range of elephant grass growth in dry area, wet season of humid tropics (Xande *et al.*, 1989). The DM content ranged from 13.2 to 17.7% in their study. The digestibility of OM, CP, CF and NFE reduced linearly with advance in mature. The digestibility of EE, however, did not show a constant trend. The decreased forage digestibility with advancing maturity is well established (Van Soest, 1994), and has also been reported with elephant grass (Ngo and Wilkitorsson, 2003). The advance of maturity increased NDF and ADF content of elephant grass, and reduced its *in situ* DM degradability (Silva *et al.*, 2008). The agronomic history of pasture (residual herbage after harvest), and its interactions with fertilization rate, type of soil, season and age of regrowth might change the leaf-to-stem ratio of tropical forages (Overman and Wilkinson, 1989). The decline in forage digestibility with age of maturity

results primarily from a decrease in leaf: stem ratio, a decline in quality of the stem fraction due to an increase in the proportion of cell wall and its lignifications (Mtengeti *et al.*, 1995; Wilman and Moghaddam, 1998) and increased proportion of the indigestible fractions. The PDIN (protein truly digestible in the small intestine when N is the limiting factor), PDIE (protein truly digestible in the small intestine when energy is the limiting factor), ME (metabolizable energy) and UFV (net energy value for meat production) values of elephant grass were reduced as aging (Table 4). Digestible energy was reduced with longer cutting interval of elephant grass (Ngo and Wilkitorsson, 2003) is in line with our results. Similarly, Abbasi *et al.* (2012) indicated that ME were reduced with plant maturity. Forage quality depends on harvest date (Nordheim-Viken and Volden, 2009). Maturity is considered to be the primary factor affecting the chemical composition and nutritional quality of most forage (Nelson and Moser, 1994). Considering the yields of grass, Ngo and Wilkitorsson (2003) reported that elephant grass should be harvested at around 6 to 8 weeks of regrowth to achieve the best balance between yield and forage quality. The present study implicated that even the nutritive values reduced with advancing maturity but DM intake increased significantly, so that it should be considered the appropriate harvesting period.

Elephant grass, with the same age of regrowth but from different locations and periods of harvesting, showed wide variations in DM and CP concentration (Table 2), DM intake and digestibility of OM, CP, CF and NFE (Table 3). These variations were due to differences in managing and season of harvest. Seasons of harvest has influence on chemical composition of forage (Yayneshet *et al.*, 2009). Nitrogen fertilization have an profound effect on CP content of bermudagrass, bahiagrass and stargrass (Johnson *et al.*, 2001) and amaranth forage (Abbasi *et al.*, 2012). The DM intake of the elephant grass, except day 40 harvested in May 2007, were comparable to elephant grass intake harvested from humid tropics and the Mediterranean area (Xande *et al.*, 1989). The variation in nutritive value of elephant grass among seasons and years in this study was in consistent with Kozloski *et al.* (2005), who reported that age of regrowth was not a good indicator of nutritional value of elephant grass. The reduced protein value with advancing maturity of forage is consistent with the findings of Aumont *et al.* (1995). They also indicated that the low PDIE and PDIN of tropical forage were due to low CP content. The protein, energy and net energy values of elephant grass in the current study were similar to those of elephant grass from humid tropics reported by Xande *et al.* (1989).

The DM content of sweet potato vine (15 %) was lower compared to results of earlier studies by Lam and Ledin (2004), Olorunnisomo (2007) and Katongole *et al.* (2008); who reported DM contents between 18 and 40%. The CP concentration was 12%, comparable to results of Kariuka *et al.* (1998) and Katongole *et al.* (2008); 13.5% and ranging from 9.9 to 12.2%, respectively; but lower compared to Lam and Ledin (2004), Olorunnisomo (2007), ranging from 19.8 to 26.7%. The DM intake in the present study was lower than findings of Olorunnisomo (2007) where sweet potato foliage was sun-dried before feeding to sheep. The lower DM intake was probably due to high moisture content and a lower CP concentration. DM intake of sweet potato foliage was much lower compared to Napier grass and Lucerne (Kariuka *et al.*, 1998) when heifer were fed on these forages as sole feed. The OM and CP digestibility was high (75.9 and 67.6, respectively) and was in accordance with previous studies (Olorunnisomo, 2007; Katongole *et al.*, 2008). The net energy values were high; 0.88 and 0.85 for UFL and UFV, respectively. The potential of sweet potato vine as forage was demonstrated by Etela *et al.* (2008) who used the material to supplement Panicum grass in the diet of pre-weaned calves. The DM intake of Panicum grass and total diet, and live weight gain were similar to supplementation with dried brewers' grains and cottonseed meal.

Maize stover had DM intake and OM digestibility of 50.5 g/kg $W^{0.75}$ and 63.0%, respectively; and net energy values of 0.73 (UFL) and 0.66 (UFV) (Table 4). Andrieu *et al.* (1989) reported results of 33 trials that whole crop maize harvested at milk stage had DM intake around 52 g/kg $W^{0.75}$, OM digestibility of 72% and net energy values (0.90 and 0.84 for UFL and UFV, respectively) which are slightly higher than those found in this study. The higher OM digestibility and nutritive values compared to this material is that grain was removed from maize forage in the current study. Maize stover silage had CP content of 8.2% which is similarly to results of Walsh *et al.* (2008), who reported CP concentration of 8.7%. Walsh *et al.* (2008) indicated that when comparing maize stover silage (MS) with whole-crop wheat harvested at a normal cutting height (WCW, stubble height 12 cm) or an elevated cutting height (HCW, stubble height 29 cm), whole-crop barley harvested at a normal cutting height (WCB, stubble height 13 cm) or an elevated cutting height (HCB, stubble height 30 cm) to fattening cattle; steers fed MS had a better feed conversion efficiency than those on WCW or WCB ($P < 0.05$) but were similar to HCW and HCB.

The CP contents (12.4% of DM) of the present Stylo grass was lower than those reported by Ba *et al.* (2013), ranging from 14.7 to 17.9% of DM. The low DM intake (42 g/kg $W^{0.75}$)

was in line with Stylo grass from dry area, wet season and 12 weeks of age in the humid tropics (Xande *et al.*, 1989). However, the OM digestibility in the study of Xande *et al.* (1989) was only 52% and their net energy values was lower than the present study. As lambs fed urea treated rice straw (URTRS) and molasses, and supplemented with one of the four treatments: 1.5% concentrate, Stylo grass, cassava foliage, or Jackfruit foliage; Hue *et al.* (2008) found that the live weight gain was similar in all treatments. In another work, growing Laisind cattle fed a basal diet of URTRS, 0.87 kg concentrate and 0.22 kg molasses; and one of the following supplements (DM basis): 0.26 kg soybean meal (CON), 0.95 kg cassava foliage (CA), 1.01 kg Stylo foliage (STY), and a mix of 0.49 kg Stylo foliage and 0.49 kg cassava foliage (CA-STY); the live weigh gain of CA-STY was higher than CA and was not significantly different compared to CON (Thang *et al.*, 2010). Fresh natural grass had CP concentration lower than that reported by Sanh *et al.* (2002). Its quality is variable and depends on many factors such as component of grass species, soil, seasons, etc. This natural grass was collected during the beginning of the dry season so its nutritive values could be lower compared to others.

Cassava tops silage had a CP content of 14.6% which was lower than the content reported by Man and Wiktorsson (2001) and Khang and Wiktorsson (2006); 21.1 and 20.3%, respectively. The current OM and CP digestibility was higher than those achieved in a previous study (Man and Wiktorsson, 2001), 52.1 and 45.8%. The stage of maturity, leaf-to-stem ratio, tannin concentration and fertilization may explain the difference in chemical composition and digestibility. Cassava foliage contains tannin which decrease DM intake (Reed *et al.*, 1990) by reducing palatability and digestibility at high tannin levels (Kumar and D'Mello, 1995) when fed as sole feed, hence resulting in low values of ME and net energy (Table 4). Growing heifers fed on URTRS basal diets supplemented with 100g CP from cassava tops silage/100 kg live weight (LW) had higher weight gain than those supplemented with 0.72 kg dry matter (DM) of Napier grass and 0.26 kg DM of cassava root meal/100 kg LW (Khang and Wiktorsson, 2006).

Nutritional values of natural grass hay was similar to those reported by Richard *et al.* (1989). The CP content and nutritive value of Bermuda grass hay was slightly lower than those reported in a previous study (Aumont *et al.*, 1995). The Guinea hay had CP concentration higher but lower DM and OM digestibility than Guinea grass hay cut at 35 days reported by Avellaneda *et al.* (2009).

3.2. Correlation among nutritional composition of elephant grass and its DM intake, digestibility

The correlation coefficients of some characteristics of elephant grass were showed in Table 5. Stage of maturity was positively correlated with DM concentration (correlation was 0.747, $P < 0.05$) and negatively correlated with CP content (correlation was -0.626, $P < 0.05$) as expected. DM intake (DMI) was positively correlated with DM and ADF concentration (correlations were 0.729 and 0.784, respectively; both $P < 0.05$) (Table 5). The significant positive correlation between DMI and DM contents ($P < 0.05$) of the elephant grass is due to the fact that the DM contents of the forage were low. Previous studies showed that reduced DM intake when DM content is low (Lahr *et al.*, 1983; Pasha *et al.*, 1994). Low DM content of fresh forages in the present study because these forages were harvested in the summer/rainy seasons. Lippke (1980) reported highly negative correlation between DM intake and ADF, which was inconsistent with our results. This may have been due to low ADF intake per kg metabolism weight of sheep in this study. There was no significant correlation between DMI and NDF (Table 5) a result which was not expected. Because NDF generally ferments and passes from the reticulorumen more slowly than other dietary constituents, it has a greater filling effect over time than non-fibrous feed components and has been found to be the best single chemical predictor of voluntary DM intake (Allen, 1996).

Digestible protein and CP (Appendix) were related by a linear equation, showing the usual strong association (correlation was 0.88) and coefficient of true digestibility, 0.89. Those results coincides with findings of Lippke (1980).

4. Conclusion

Elephant grass, cultivated in the same management condition, reduced its nutritive values by increased ages, but the DM intake at 75 days was higher than those harvested at 65, 55 and 45 days. There were variations in chemical composition, DM intake and net energy values of elephant grass harvested at similar ager but different locations and years.

Sweet potato vine has a potential as forage if the DM intake could be higher by wilting before feeding. Maize stover, maize stover silage, Stylo grass and natural grass were all good quality forage and their DM intakes were acceptable. Cassava tops silage could be used as a protein supplemental source. Bermuda hay, natural grass hay and Guinea hay had medium quality but DM intakes were good.

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Appendix

Predicted DM intake of elephant grass

The GLM procedures on the results of DM intake of all 11 elephant grass collected led to the equation:

$$\text{DMI} = 130 + 0.787 \text{ Days} + 2.52 \text{ DM} + 1.71 \text{ CF} - 4.81 \text{ NDF} + 2.49 \text{ ADF}$$

Where DMI was calculated in present, and chemical compositions (DM, CF, NDF and ADF) was expressed in g/kg DM. ($P = 0.002$; $R^2_{\text{adjusted}} = 0.92$; $\text{RSD} = 2.69519$; $n = 11$)

Predicted OM digestibility

The GLM procedures on the results of digestibility of all 15 fresh forages collected led to the equation:

$$\text{OMD} = 28.7 + 0.954 \text{ CP} - 1.25 \text{ CF} + 1.38 \text{ Ash} + 1.35 \text{ ADF} \quad (1)$$

Where OMD was calculated in present, and chemical compositions (CP, CF, Ash and ADF) was expressed in g/kg DM. ($P = 0.002$; $R^2_{\text{adjusted}} = 0.71$; $\text{RSD} = 2.36652$; $n = 15$)

And the OMD predicted equation for elephant grass only ($P = 0.025$; $R^2_{\text{adjusted}} = 0.68$; $\text{RSD} = 2.21438$; $n = 11$):

$$\text{OMD} = 26.3 + 0.936 \text{ CP} - 1.21 \text{ CF} + 1.44 \text{ Ash} + 1.37 \text{ ADF} \quad (2)$$

Digestible crude protein (DCP, g/kg DM) was predicted by equation:

$$\text{DCP} = -29.6 + 9.12 \text{ CP}$$

Where DCP was calculated in current data for all 20 samples of the collected feedstuff ($P = 0.000$; $R^2_{\text{adjusted}} = 0.89$; $\text{RSD} = 9.17133$; $n = 20$).

Table 2. Chemical composition of forages (%).

	Harvested	DM	CP	EE	CF	Ash	NDF	ADF	OM	NFE
UNCONSERVED										
Natural grass	Oct, 2005	17.7 ± 1.9	9.6 ± 1.3	2.1 ± 0.2	26.6 ± 1.9	13.5 ± 0.4	62.0 ± 3.0	32.6 ± 1.1	86.5 ± 0.4	48.3 ± 1.2
Maize stover (without grain)	Dec, 2006	20.5 ± 1.7	11.1 ± 1.4	0.9 ± 0.3	29.0 ± 0.8	8.7 ± 0.3	66.0 ± 0.8	35.2 ± 1.7	91.3 ± 0.3	50.4 ± 1.2
Sweet potato vine	Oct, 2006	15.0 ± 0.2	12.1 ± 0.3	2.4 ± 0.2	19.0 ± 0.1	12.1 ± 0.2	72.2 ± 9.6	30.7 ± 0.5	87.9 ± 0.2	54.5 ± 0.5
Stylo grass	Jul, 2006	25.7 ± 0.3	12.4 ± 0.7	1.6 ± 0.1	40.8 ± 0.8	7.4 ± 0.3	65.8 ± 0.6	45.7 ± 0.3	92.6 ± 0.3	37.9 ± 0.2
Elephant grass (regrowth, days) ^A										
40	Jun, 2006	12.4 ± 0.1	14.3 ± 0.2	2.2 ± 0.1	39.7 ± 1.2	14.2 ± 0.1	62.8 ± 0.2	37.1 ± 0.4	85.9 ± 0.1	29.6 ± 1.4
40	May, 2007	8.1 ± 0.0	16.5 ± 0.6	2.7 ± 0.1	29.8 ± 0.6	11.1 ± 0.0	59.5 ± 2.6	35.5 ± 1.8	88.9 ± 0.0	39.9 ± 0.1
50	Aug, 2006	13.7 ± 0.2	10.0 ± 0.0	2.5 ± 0.5	33.6 ± 0.3	12.4 ± 0.5	63.7 ± 1.3	35.2 ± 0.7	87.6 ± 0.5	41.6 ± 0.3
55	Nov, 2006	18.8 ± 1.1	11.5 ± 0.4	2.0 ± 0.0	32.9 ± 1.1	9.8 ± 0.2	64.9 ± 1.3	36.3 ± 0.8	90.2 ± 0.2	43.8 ± 0.6
60	Sept, 2005	19.9 ± 3.7	8.9 ± 1.2	2.0 ± 0.2	35.0 ± 2.2	12.2 ± 0.6	67.3 ± 1.8	40.8 ± 2.5	87.8 ± 0.6	41.8 ± 1.9
60	Nov, 2006	16.7 ± 0.1	11.4 ± 0.4	1.6 ± 0.1	32.3 ± 0.2	11.4 ± 0.4	66.8 ± 1.0	38.1 ± 0.0	88.6 ± 0.4	43.3 ± 0.6
60	May, 2007	15.5 ± 0.6	16.0 ± 0.2	2.4 ± 0.3	34.6 ± 1.9	12.4 ± 0.0	66.6 ± 1.2	38.3 ± 0.8	87.6 ± 0.0	34.6 ± 1.8
Elephant grass (regrowth, days) ^B										
45	Oct, 2007	11.9 ± 0.8	11.0 ± 0.3	2.1 ± 0.1	28.1 ± 1.8	16.2 ± 0.2	60.1 ± 2.4	32.7 ± 2.1	83.8 ± 0.2	42.6 ± 1.7
55	Oct, 2007	13.9 ± 1.1	8.7 ± 1.0	1.9 ± 0.1	31.5 ± 1.1	15.3 ± 1.6	65.3 ± 0.1	35.6 ± 0.2	84.7 ± 1.6	42.6 ± 1.6
65	Oct, 2007	14.9 ± 1.0	7.8 ± 1.0	1.9 ± 0.3	31.0 ± 2.8	13.5 ± 0.4	67.3 ± 0.1	36.7 ± 0.0	86.5 ± 0.4	45.8 ± 1.1
75	Oct, 2007	18.0 ± 0.5	7.6 ± 0.6	2.2 ± 0.4	30.2 ± 0.7	12.9 ± 0.9	68.3 ± 1.7	34.7 ± 1.5	87.1 ± 0.9	47.1 ± 2.6
SILAGE										
Maize stover	2005	19.0 ± 1.5	8.2 ± 0.3	1.8 ± 0.1	33.8 ± 0.7	13.3 ± 0.1	68.9 ± 0.3	39.1 ± 0.2	86.7 ± 0.1	43.0 ± 0.9
Cassava tops	2007	28.3 ± 0.3	14.6 ± 0.4	5.4 ± 0.1	18.8 ± 0.6	16.0 ± 0.0	42.3 ± 0.7	29.4 ± 0.4	84.0 ± 0.0	45.1 ± 1.1

HAY

Bermuda hay	2005	92.2 ± 1.1	7.1 ± 0.2	1.6 ± 0.1	25.6 ± 0.7	8.6 ± 0.4	71.0 ± 2.0	32.9 ± 1.8	91.4 ± 0.4	57.1 ± 1.0
Natural grass hay	2005	89.3 ± 1.4	9.2 ± 0.3	1.1 ± 0.0	29.4 ± 1.0	13.3 ± 2.1	68.2 ± 4.0	35.4 ± 1.5	86.7 ± 2.1	47.1 ± 1.3
Guinea hay	2006	91.2 ± 1.0	14.8 ± 0.7	0.8 ± 0.1	34.2 ± 2.1	10.9 ± 0.4	74.1 ± 1.2	41.3 ± 0.9	89.1 ± 0.4	39.3 ± 2.3

DM dry matter; *CP* crude protein; *EE* ether extract; *CF* crude fiber; *NDF* neutral detergent fiber; *ADF* acid detergent fiber; *OM* organic matter; *NFE* nitrogen free extracts (100 - (CP + EE + CF + Ash))

^A Grass from different fertilizations and locations; ^B Grass from the same management and location

Table 3. Intake (g DM/kg W^{0.75}) and the coefficient of apparent digestibility (g/100g DM) of tested forages.

	Harvested	DMI	DM	CP	EE	CF	Ash	NDF	ADF	OM	NFE
UNCONSERVED											
Natural grass	Oct, 2005	50.4 ± 2.3	57.9 ± 3.2	55.3 ± 2.9	56.4 ± 1.8	55.3 ± 3.5	30.3 ± 2.3	59.0 ± 3.2	53.7 ± 3.7	62.9 ± 3.1	69.7 ± 2.5
Maize stover (without grain)	Dec, 2006	50.5 ± 3.6	61.6 ± 0.7	71.6 ± 0.5	39.4 ± 1.2	62.5 ± 2.0	42.4 ± 0.6	61.9 ± 1.0	62.8 ± 2.0	63.8 ± 1.3	63.7 ± 0.7
Sweet potato vine	Oct, 2006	35.2 ± 1.8	73.6 ± 0.9	67.6 ± 2.6	62.7 ± 3.5	59.1 ± 3.7	56.4 ± 5.2	81.0 ± 0.9	69.4 ± 2.1	75.9 ± 1.1	84.6 ± 1.4
Stylo grass	Jul, 2006	42.0 ± 1.5	50.6 ± 2.4	56.7 ± 2.4	22.9 ± 5.7	51.2 ± 3.6	18.8 ± 3.2	48.2 ± 3.2	48.2 ± 2.6	53.1 ± 5.2	55.3 ± 3.5
Elephant grass (regrowth, days) ^A											
40	Jun, 2006	48.4 ± 5.9	69.8 ± 2.1	76.4 ± 1.8	59.3 ± 0.6	76.2 ± 2.5	63.9 ± 1.6	70.1 ± 1.3	71.8 ± 2.0	64.8 ± 1.3	54.9 ± 2.8
40	May, 2007	34.2 ± 3.0	70.8 ± 2.1	79.0 ± 2.6	72.8 ± 4.1	73.6 ± 1.8	63.4 ± 7.6	73.1 ± 1.1	74.9 ± 1.7	72.5 ± 1.3	68.1 ± 1.9
50	Aug, 2006	44.4 ± 3.1	56.2 ± 2.9	56.3 ± 4.9	59.6 ± 5.1	58.6 ± 3.5	37.2 ± 4.7	55.8 ± 2.9	55.7 ± 3.2	58.9 ± 2.8	60.4 ± 2.1
55	Nov, 2006	53.8 ± 3.3	58.5 ± 0.3	66.3 ± 1.0	52.4 ± 6.3	60.7 ± 2.0	27.2 ± 1.2	57.3 ± 3.6	58.7 ± 3.6	60.4 ± 3.9	59.3 ± 5.1
60	Sept, 2005	65.4 ± 4.0	61.4 ± 3.5	60.9 ± 1.1	59.5 ± 4.9	69.3 ± 2.7	29.3 ± 1.0	67.1 ± 0.9	69.3 ± 2.0	65.9 ± 2.6	67.1 ± 2.0
60	Nov, 2006	45.6 ± 1.2	66.7 ± 0.8	75.7 ± 1.0	53.2 ± 5.3	68.8 ± 1.9	49.0 ± 1.6	68.8 ± 0.3	70.4 ± 2.3	67.9 ± 2.0	66.6 ± 2.1
60	May, 2007	53.3 ± 4.3	63.7 ± 4.0	78.8 ± 3.0	64.0 ± 5.6	66.7 ± 6.3	45.3 ± 4.2	65.8 ± 4.9	67.5 ± 6.7	66.3 ± 4.3	60.2 ± 4.3
Elephant grass (regrowth, days) ^B											
45	Oct, 2007	35.6 ^b ± 1.8	65.2 ± 2.5	70.0 ^a ± 1.7	68.3 ± 1.5	72.7 ^a ± 2.5	41.6 ± 3.5	69.4 ± 3.1	71.5 ± 2.7	69.8 ^a ± 2.3	67.8 ^a ± 2.6
55	Oct, 2007	38.4 ^b ± 1.3	64.4 ± 1.4	63.1 ^b ± 2.4	69.2 ± 1.5	72.6 ^a ± 1.6	44.6 ± 2.6	68.3 ± 2.0	69.7 ± 1.9	67.9 ^{ab} ± 1.3	65.4 ^{ab} ± 1.7
65	Oct, 2007	36.5 ^b ± 2.1	62.6 ± 1.2	62.7 ^{bc} ± 1.5	67.7 ± 3.5	66.2 ^b ± 2.6	44.6 ± 1.1	63.9 ± 1.9	66.4 ± 3.2	65.5 ^{bc} ± 1.4	65.3 ^{ab} ± 0.6
75	Oct, 2007	43.0 ^a ± 1.8	59.3 ± 1.3	58.7 ^c ± 2.4	66.4 ± 2.3	64.0 ^b ± 2.1	34.2 ± 3.0	62.9 ± 1.6	63.0 ± 2.8	63.7 ^c ± 2.1	63.7 ^b ± 2.1
SILAGE											
Maize stover	2005	53.3 ± 2.7	59.9 ± 3.0	48.5 ± 2.7	70.9 ± 2.4	69.6 ± 4.3	47.3 ± 2.6	64.2 ± 3.3	67.2 ± 3.5	61.8 ± 3.2	57.8 ± 3.1
Cassava tops	2007	46.1 ± 1.5	56.0 ± 1.1	58.1 ± 4.6	34.5 ± 2.7	38.3 ± 1.4	68.5 ± 1.8	35.3 ± 1.5	34.1 ± 3.6	53.6 ± 1.3	62.2 ± 3.6

HAY

Bermuda hay	2005	63.2 ± 4.9	58.3 ± 1.0	44.7 ± 1.8	72.9 ± 2.1	54.7 ± 4.7	28.2 ± 3.1	59.1 ± 0.6	55.3 ± 1.0	61.2 ± 0.9	65.9 ± 1.8
Natural grass hay	2005	62.8 ± 6.8	52.7 ± 2.4	48.2 ± 3.0	31.6 ± 5.3	57.7 ± 3.4	34.3 ± 2.7	55.3 ± 2.9	52.9 ± 4.1	55.3 ± 2.5	56.2 ± 2.1
Guinea hay	2006	51.6 ± 1.7	54.2 ± 2.0	62.2 ± 1.6	32.3 ± 5.9	64.8 ± 3.2	32.2 ± 1.6	65.0 ± 1.7	66.8 ± 3.0	56.9 ± 2.1	49.3 ± 1.9

^{a, b, c} Means of the same column within the same harvesting months of elephant grass with different superscript were significant different (P<0.05).

DMI dry matter intake; *DM* dry matter; *CP* crude matter; *EE* ether extract; *CF* crude fiber; *NDF* neutral detergent fiber; *ADF* acid detergent fiber; *OM* organic matter; *NFE* nitrogen free extracts (100 - (CP + EE + CF + Ash)).

^A Grass from different fertilizations and locations; ^B Grass from the same management and location

Table 4. Nutritive values of forages calculated according to the INRA system.

	Harvested	Protein value (g/kg DM)				Energy value (MJ/kg DM)				Net energy (per kg DM)	
		DCP	PDIA	PDIN	PDIE	GE	DE	ME	UFL	UFV	
UNCONSERVED											
Natural grass	Oct, 2005	53	32	61	72	16.5	10.2	8.36	0.69	0.61	
Maize stover (without grain)	Dec, 2006	79	37	71	80	17.4	10.9	8.90	0.73	0.66	
Sweet potato vine	Oct, 2006	82	40	77	95	16.8	12.5	10.31	0.88	0.85	
Stylo grass	July, 2006	70	41	79	80	17.7	9.2	7.38	0.58	0.49	
Elephant grass (regrowth, days) ^A											
40	June, 2006	110	48	92	91	16.4	10.5	8.33	0.68	0.61	
40	May, 2007	130	55	105	105	17.0	12.1	9.72	0.82	0.77	
50	Aug, 2006	56	33	64	75	16.7	9.7	7.85	0.64	0.55	
55	Nov, 2006	76	38	73	82	17.2	10.2	8.27	0.67	0.59	
60	Sept, 2005	54	30	57	78	16.8	10.9	8.81	0.73	0.66	
60	May, 2007	87	38	73	88	16.9	11.3	9.14	0.76	0.70	
60	Nov, 2006	126	53	102	98	16.8	10.9	8.72	0.72	0.65	
Elephant grass (regrowth, days) ^B											
45	Oct, 2007	77	37	70	84	16.0	11.0	8.95	0.75	0.70	
55	Oct, 2007	55	29	56	77	16.2	10.8	8.80	0.73	0.67	
65	Oct, 2007	49	26	50	74	16.5	10.6	8.69	0.72	0.65	
75	Oct, 2007	45	26	49	72	16.6	10.4	8.52	0.70	0.63	

Table 5. The correlation coefficients of some characteristics of elephant grass.

	Days	DMI	DM	CP	NDF	ADF
DMI	0.226					
	0.504					
DM	0.747	0.729				
	0.008	0.011				
CP	- 0.626	0.014	- 0.535			
	0.039	0.969	0.090			
NDF	0.908	0.470	0.832	- 0.550		
	0.000	0.144	0.001	0.080		
ADF	0.239	0.784	0.521	0.089	0.541	
	0.478	0.004	0.100	0.795	0.086	
CPD	- 0.484	- 0.090	- 0.466	0.880	- 0.416	0.130
	0.131	0.792	0.149	0.000	0.204	0.703

Days age of grass (regrowth days); *DMI* dry matter intake; *DM* dry matter content; *CP* crude protein content; *NDF* neutral detergent fiber; *ADF* acid detergent fiber; *CPD* crude protein digestibility

Paper II

*Influence of varying levels of supplemental
cassava root meal without or with
groundnut cake on performance of growing
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Influence of varying levels of supplemental cassava root meal without or with groundnut cake on performance of growing Laisind cattle

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Abstract The objective of this study was to evaluate the effect of supplementation of varying levels of cassava root meal (CRM, 300 and 1,000 g), without or with 700 g groundnut cake (GNC) on intake and performance of growing Laisind cattle fed with a basal diet of urea-treated rice straw (URTRS). Twenty-four male cattle of crossbred Laisind (50 % Red Sindhi and 50 % local Yellow, both *Bos indicus*), from 15 to 17 months of age, 165–175 kg body weight, were used. They were assigned to a completely randomized block design in a 2×2 factorial arrangement (two CRM levels and two GNC levels). Intake of URTRS (interaction, $P<0.01$) and digestibility of neutral detergent fiber (interaction, $P<0.05$) decreased as CRM level increased on the diets without GNC but was not affected by CRM level on the diets with GNC. The total dry matter intake (interaction, $P<0.05$) and live weight gain (LWG) (interaction, $P<0.001$) increased as CRM level increased on the diets with GNC, but no difference was observed on the diets without GNC. In conclusion, supplementation of 1,000 g CRM should be in combination with 700 g GNC to avoid the negative effects on URTRS intake and digestibility, therefore improving LWG of growing Laisind cattle fed on a URTRS-based diet.

Keywords Laisind beef cattle · Growth phase · Cassava root meal · Groundnut cake · Urea-treated rice straw

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Introduction

Basal diet of rice straw (RS) is usually fed to ruminants during drought season in Vietnam. However, RS is low in nutritive value and poor in digestibility. Urea treatment improves RS quality and currently seems to be practical for on-farm use. When animals are fed on urea-treated rice straw (URTRS), a supplementary strategy is necessary for optimum performance.

Cassava root meal (CRM) has high level of starch (Mejia-Agüero et al. 2012), which provides readily fermentable energy for fermentation in the rumen. Supplementation with starch improved growth but reduced URTRS intake and neutral detergent fiber (NDF) digestibility at high supplemental levels (Wanapat and Khampa 2007). By contrast, low levels of starch tended to increase RS intake and have not depressed NDF digestibility (Zhang et al. 2010). However, when ruminants are supplemented low levels of starch, there is often a decrease in performance compared to those supplemented higher levels (Ba et al. 2008; Thang et al. 2010), due to lack of energy.

Groundnut cake is a by-product of extracting oil industry and is a locally available protein source. Its price is reasonable compared to other true protein sources (i.e., oilseed and fish meal) in the region. Groundnut cake (GNC) has rumen degradable protein (RDP) of around 80 % of the total protein (Mondal et al. 2008). Supplementation of RDP (i.e., casein) overcomes negative effects of supplemental starch on NDF digestion (Klevesahl et al. 2003). Cattle performance, forage intake, and NDF digestion with true protein supplements were higher than those of cattle receiving nonprotein nitrogen supplements (Arroquy et al. 2004). Supplementing true protein and energy simultaneously to low-quality roughage basal diets resulted in additive response in live weight gain (LWG) of ruminants (Bodine and Purvis II 2003; Nhiem et al. 2013). Nevertheless, CRM and/or GNC have not yet been used on

URTRS-based diets. Therefore, the objective of this research was to determine the effect of supplemental CRM without or with GNC on intake, digestibility, and performance of growing Laisind cattle.

Materials and methods

The study was conducted from December 2009 to March 2010 at the Bavi Forage and Cattle Research Centre in northern Vietnam. The climate is tropical monsoon with a wet season between April and November and a dry season from December to March.

Experimental feeds

The basal diet was URTRS ad libitum and 2.0 kg of maize stover silage (MS). Urea treatment was achieved by spraying an aqueous solution containing urea (40 g/kg) and water (800 g/kg) on the basis of the air-dry weight of RS (91 % dry matter (DM)) in the container and was then sealed up for a minimum 3 weeks before feeding directly to animals. The maize stover, harvested after collecting the young grain, was ensiled with 5 % of CRM and 1 % of common salt. The MS was fed to the cattle after 1 month ensiling. Supplemental feeds, CRM, and GNC were purchased from the local market.

Animals, experimental design, and management

Twenty-four male cattle of crossbred Laisind (50 % Red Sindhi and 50 % local Yellow, both *Bos indicus*) from 15 to 17 months of age, 165–175 kg body weight (BW), were used in the study. Before the start of the experiment, all cattle were ear-tagged for identification, vaccinated against food and mouth disease by Aftovar (2 ml/head), 2 weeks later, for pasteurellosis using P52 (2 ml/head), and dewormed with ivermectin 2.5 (1 ml/12 kg BW). The vaccines and drugs were produced by NAVETCO Co., Ltd, Vietnam. The animals were housed in individual pens with individual feeder and had free access to water.

Cattle were adapted for 4 weeks to the surrounding environment and for another 2 weeks to the experimental diet before starting the 98-day growth experiment. The digestion trial was carried out from days 63 to 69 in the growth experiment.

The experiment was organized as a 2 × 2 factorial completely randomized block design, two levels of CRM (300 and 1,000 g) and without or with 700 g GNC. The four treatments were as follows: (1) basal diet plus 300 g CRM, (2) basal diet plus 1,000 g CRM, (3) basal diet plus 300 g CRM and 700 g GNC, and (4) basal diet plus 1,000 g CRM and 700 g GNC. Each cattle was also supplemented with 40 g bone meal and 30 g vitamin-mineral premix. Animals were given supplements in two equal amounts twice daily, MS once daily, and URTRS ad libitum. Chemical composition and estimated

metabolizable energy (ME) content of feeds are shown in Table 1.

Measurements

Feed offered and refused were recorded daily during the growth experiment. Refusals were removed and weighed before the morning feeding. Samples of feeds offered and refusals were taken twice a week, and cattle were weighed weekly. During the digestibility trial, samples of each feed were taken every day and bulked separately in marked bags. Refusals were removed daily, weighed, sampled, and bulked in individual bags. The total daily feces output for each cattle was collected, weighed, sampled, and pooled for the whole digestion trial.

Chemical analysis

The samples of feeds, refusals, and feces were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), and ash contents. DM (ID 930.15) and CP (ID 976.05) were analyzed according to methods of the AOAC (1990). The EE was analyzed by ISO (6492:1999), NDF and ADF were determined by the methods of Goering and Soest (1970), and ash (ID 942.05) was analyzed according to the standard of AOAC (1990).

Statistical analysis

The data were analyzed statistically by analysis of variance (ANOVA) using the general linear model least squares procedures of Statistical Analysis Systems Institute (SAS 1996). The statistical model used was $Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \gamma_k + \varepsilon_{ijk}$ where: Y_{ijk} is the dependent variable, μ is the overall mean, α_i is the effect of CRM level i , β_j is the effect of the GNC level j , $(\alpha\beta)_{ij}$ is the effect of interaction of CRM and GNC, γ_k is the effect of the k_{th} block, and ε_{ijk} is the random error. When the treatment least square means showed a significant difference at $P \leq 0.05$, Tukey's procedure was applied for pairwise comparison of means.

Results

Feed and nutrient intake

Intake of URTRS (interaction, $P < 0.01$) decreased as CRM level increased on the diets without GNC but was not affected by CRM level on the GNC diets. The total DM intake (interaction, $P < 0.05$) increased as CRM level increased on the GNC diets, but no difference was observed on the diets without GNC (Table 2).

Table 1 Chemical composition and estimated metabolizable energy (ME) content of experimental feeds (mean and S.D.)

Item	Urea-treated rice straw	Maize stover silage	Cassava root meal	Groundnut cake
ME ^A , MJ/kg DM	5.5 (0.2)	9.4 (0.4)	13.1 (0.3)	11.5 (0.2)
DM, g/kg	461 (44.1)	254 (25.4)	893 (14.6)	909 (19.6)
In g/kg DM				
Organic matter	854 (11.9)	922 (5.1)	981 (3.3)	946 (9.3)
Crude protein	114 (15.1)	94 (2.6)	22 (6.0)	293 (9.4)
Ether extract	8 (2.2)	16 (2.3)	10 (4.6)	147 (8.5)
Neutral detergent fiber	691 (33.1)	563 (19.2)	79 (12.3)	329 (13.9)
Acid detergent fiber	433 (27.0)	307 (12.7)	48 (8.6)	206 (11.2)
RDP	NA	NA	NA	234.4 ^B
Starch	NA	NA	790 ^C	83 ^D
HCN, mg	NA	NA	53 ^E	NA

MJ megajoule, DM dry matter, RDP rumen degradable protein, HCN hydrogen cyanide, NA not analyzed

^A Calculated based on the in vitro gas production method and the equations of Menke and Steingass (1988)

^B Data from Mondal et al. (2008)

^C Data of Mejía-Agüero et al. (2012)

^D Based on the findings of Venkatesh et al. (2009)

^E Estimated from Thang et al. (2010)

Intake of ME (interaction, $P < 0.05$) and digestible organic matter (OM) (interaction, $P < 0.01$) increased as CRM level increased on each GNC level. Intake of CP (interaction, $P < 0.01$) was not affected by increased CRM level on each GNC level, but increased as GNC level increased on the same CRM level (Table 2).

Cattle offered higher CRM levels had a significantly higher starch (0.37 versus 0.13 % of BW; $P < 0.001$) and hydrogen cyanide (HCN) intake (0.23 versus 0.07 mg/kg BW, $P < 0.001$) compared to cattle offered low CRM levels. Cattle offered GNC had a significantly higher RDP intake (0.14 versus 0.0 kg/day; $P < 0.001$) compared to cattle offered without GNC. The CRM by GNC interaction ($P < 0.05$) was detected on the ratio of digestible OM to CP; which varied from 4.33 to 6.26 (Table 2).

Live weight change and feed conversion ratio

There was CRM by GNC interaction for the final live weight (FLW) ($P < 0.001$) and live weight gain (LWG) ($P < 0.001$). Cattle offered 1,000 g CRM were heavier (221 versus 202 kg; $P < 0.001$) and gained more weight (0.55 versus 0.37 kg/day; $P < 0.001$) than those offered 300 g CRM on the GNC diets. However, no difference was observed on the diets without GNC (Table 3).

Cattle offered 1,000 g CRM improved feed conversion ratio (FCR)_{DM} (11.5 versus 13.0 kg DM/kg LWG; $P < 0.01$) compared to those offered 300 g CRM. Cattle offered 700 g GNC improved FCR_{DM} (10.4 versus 14.1 kg DM/kg LWG; $P < 0.001$) compared to those offered without GNC (Table 3).

Table 3 also shows interactions between CRM and GNC on FCR_{ME} ($P < 0.01$) and protein efficiency ratio (PER) ($P < 0.05$). Cattle offered 1,000 g CRM improved FCR_{ME} compared to those offered 300 g on the GNC diets, while there was no significant effect of CRM levels on the diets without GNC. Higher CRM levels improved PER compared to low CRM levels within each GNC level. The improvement in PER on the diets without GNC was 0.24 ($P < 0.01$), and on the GNC diets was 0.41 kg CP/kg LWG ($P < 0.01$).

The coefficient of digestibility

Higher levels of CRM resulted in cattle having significantly higher OM (0.66 versus 0.63; $P < 0.01$) and CP digestibility (0.59 versus 0.55; $P < 0.05$) compared to those offered low levels of CRM. Supplementation of GNC resulted in cattle having significantly higher digestibility of OM (0.66 versus 0.63; $P < 0.01$) and CP (0.61 versus 0.52; $P < 0.001$) compared to those offered non-GNC (Table 4).

Digestibility of NDF (interaction, $P < 0.05$) decreased as CRM level increased on the diets without GNC but was not affected on the diets with GNC (Table 4).

Discussion

Feed intake

The interaction between CRM and GNC on URTRS intake was a result of difference in NDF digestibility. Dixon and Stockdale (1999) showed that reduced NDF digestion is a

Table 2 Effects of cassava root meal (CRM) and/or groundnut cake (GNC) supplementation on feed and nutrient intake of growing Laisind cattle. Least square means and standard error of mean (SEM)

GNC, g/day	0		700		SEM	Significance		
	CRM, g/day	1,000	300	1,000		CRM	GNC	CRM*GNC
DM intake								
URTRS, % of BW	1.79 ^a	1.54 ^b	1.52 ^b	1.64 ^{ab}	0.054	NS	NS	**
MS, % of BW	0.25	0.27	0.27	0.25	NA	NA	NA	NA
Supplement, % of BW	0.18	0.51	0.51	0.79	NA	NA	NA	NA
Total diet DM, % of BW	2.23 ^b	2.30 ^b	2.28 ^b	2.68 ^a	0.054	**	**	*
Nutrient intake, total diet								
ME, MJ/day	25.9 ^c	31.3 ^b	30.2 ^b	39.1 ^a	0.67	***	***	*
CP, kg/day	0.42 ^b	0.38 ^b	0.54 ^a	0.59 ^a	0.012	NS	***	**
Digestible OM, kg/day	2.11 ^c	2.39 ^b	2.34 ^b	2.98 ^a	0.045	***	***	**
NDF, kg/day	2.54 ^{ab}	2.28 ^b	2.41 ^b	2.70 ^a	0.065	NS	*	***
ADF, kg/day	1.57 ^{ab}	1.41 ^b	1.49 ^b	1.67 ^a	0.041	NS	*	***
RDP, kg/day	0.00	0.00	0.14	0.14	0.004	NS	***	NS
Starch, % of BW	0.12 ^b	0.37 ^a	0.14 ^b	0.37 ^a	0.009	***	NS	NS
HCN, mg/kg BW	0.08	0.24	0.07	0.23	0.006	***	NS	NS
Digestible OM:CP	5.09 ^b	6.26 ^a	4.33 ^c	5.09 ^b	0.07	***	***	*

Mean within rows with different superscript letters are significantly different ($P < 0.05$)

DM dry matter, URTRS urea-treated rice straw, BW body weight, MS maize stover silage, ME metabolizable energy, MJ megajoule, CP crude protein, OM organic matter, NDF neutral detergent fiber, ADF acid detergent fiber, RDP rumen degradable protein, HCN hydrogen cyanide, NS nonsignificant, NA not analyzed

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

primary cause of substitution of supplement for forage. Supplementation with increasing amounts of CRM resulted in linear reduction of forage intake in growing cattle (Wanapat and Khampa 2007; Ba et al. 2008) and sheep (Kozloski et al. 2006). The interaction between CRM and GNC on the total DM intake was due to improved intake of URTRS and supplements by supplementation of 1,000 g CRM compared to 300 g CRM in the presence of GNC. The HCN intake of cattle

in the current experiment was much lower than the toxic dose reported by Majak (1992), who indicated that 2 mg/kg BW is considered to be lethal for ruminants.

Live weight change and FCR

The CRM by GNC interaction for LWG and FCR occurred due to either higher digestible OM intake (DOMI) and/or

Table 3 Effects of cassava root meal (CRM) and/or groundnut cake (GNC) supplementation on live weight gain (LWG) and feed conversion

ratio (FCR) of growing Laisind cattle. Least square means and standard error of mean (SEM)

GNC, g/day	0		700		SEM	Significance		
	CRM, g/day	1,000	300	1,000		CRM	GNC	CRM*GNC
Initial weight, kg	169	168	166	166	1.59	NS	NS	NS
Final weight, kg	197 ^b	198 ^b	202 ^b	221 ^a	1.65	***	***	***
LWG, kg/day	0.28 ^c	0.31 ^c	0.37 ^b	0.55 ^a	0.01	***	***	***
FCR _{DM} (kg DM/kg LWG)	14.5 ^c	13.7 ^c	11.5 ^b	9.3 ^a	0.4	**	***	NS
FCR _{ME} (MJ ME/kg LWG)	92.3 ^{bc}	102.1 ^b	82.8 ^c	72.0 ^a	2.6	NS	***	**
PER (kg CP/kg LWG)	1.49 ^c	1.25 ^b	1.48 ^c	1.07 ^a	0.04	***	*	*
Feed cost (1,000 VND/kg LWG)	37.1 ^{bc}	40.2 ^c	35.4 ^b	28.3 ^a	1.02	NS	***	***

Mean within rows with different superscript letters are significantly different ($P < 0.05$)

PER protein efficiency ratio, VND Vietnamese dong, NS nonsignificant

Table 4 Effects of cassava root meal (CRM) and/or groundnut cake (GNC) supplementation on nutrient digestibility of growing Laisind cattle. Least square means and standard error of mean (SEM)

GNC, g/day	0	0	700	700	SEM	Significance		
						CRM	GNC	CRM*GNC
CRM, g/day	300	1,000	300	1,000				
Organic matter	0.62 ^b	0.65 ^a	0.64 ^{ab}	0.67 ^a	0.008	**	**	NS
Crude protein	0.51 ^c	0.53 ^{bc}	0.59 ^{ab}	0.64 ^a	0.014	*	***	NS
Neutral detergent fiber	0.65 ^a	0.60 ^b	0.64 ^a	0.64 ^a	0.008	**	NS	*
Acid detergent fiber	0.63 ^a	0.58 ^b	0.59 ^b	0.57 ^b	0.007	***	**	NS

Mean within rows with different superscripts are significantly different ($P < 0.05$)

NS nonsignificant

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

improved efficiency of protein utilization (EPU) in both ruminal fermentation and metabolic protein status of cattle offered 1,000 g CRM compared to 300 g CRM on the GNC diets. The higher DOMI would provide a greater supply of energy to host animals and the synthesis of ruminal microbial. Davies et al. (2013) observed the higher dietary starch level enhanced microbial N flow to the duodenum and microbial efficiency as compared with those on low starch level at the high RDP diet. In the current study, the CP intake of cattle offered 1,000 g CRM was not significantly different to those offered 300 g CRM, although slightly higher; the former had much higher LWG (49 %) compared to those of the latter. Similarly, growing Laisind cattle given diets having the same CP intake, the LWG was 53 % higher in cattle given the high ME diet than those given the lower ME diet (Thang et al. 2010). Animals did not respond or responded with a very low efficiency to the additional protein supply when energy intake was a limiting factor (Schroeder and Titgemeyer 2008). Moreover, the improvement on EPU because of protein is only possible because some energy is already available in the metabolism (Detmann et al. 2014). Such improvements in EPU together with increased DOMI are thought to contribute to enhanced growth performance of cattle offered 1,000 g CRM with 700 g GNC. Improvements in LWG and FCR by supplementation of both energy and protein to cattle fed on forage-based diets were additive to response from supplementation with energy or protein individually (Bodine and Purvis II 2003; Nhiem et al. 2013). Their finding were similar to the current results when supplementing GNC to 1,000 g CRM but was not the case as GNC addition to 300 g CRM. This inconsistent response has been due to differences in sources and quantity of supplemental protein and energy, leading to different effects on forage intake between treatments and among trials. In the absence of GNC, supplementing 1,000 g CRM failed to improve LWG compared to 300 g CRM, which was partly due to substitution of supplements for URTRS. The present experiment demonstrates the importance of both

sufficient amounts of CRM and GNC supplementation of URTRS to achieve a desired level of performance.

In the current study, a CRM by GNC interaction for feed cost also was found. This interaction might be of important practical implications for livestock producers or farmers when supplementation to a URTRS-based diet of growing cattle. Additions of 1,000 g CRM was not an economic benefit compared to 300 g CRM given alone. Supplementing both 1,000 g CRM and 700 g GNC resulted in 24 % lower (28,000 versus 37,000 VND/kg LWG) total expenditure for feed per kilogram LWG compared to supplementation of only 300 g CRM.

The coefficient of digestibility

Similar to our results, increasing supplemental CRM resulted in increasing OM (Thang et al. 2010) and CP digestibility (Kozloski et al. 2006; Ba et al. 2008). The current findings were in line with previous authors (Bodine and Purvis II 2003; Nhiem et al. 2013) supplementing true protein increased digestibility of OM and CP.

The CRM by GNC interaction for NDF digestibility was most likely that increasing starch in the diet results in increase in the lag phase before the start of fiber digestion (Huhtanen et al. 2008) and a decrease in the rate of NDF digestion (Souza et al. 2010). Additionally, CRM has high starch content (Mejía-Agüero et al. 2012) and is extensively and rapidly fermented in the rumen (Chanjula et al. 2003), thus at higher intake, could have led to a subacute rumen acidosis, which suppress cellulolytic activity. Kozloski et al. (2006) observed a linear decrease in NDF digestibility as increasing CRM supplement at 5, 10, and 15 g/kg LW of lambs even when nitrogen was not limiting for rumen bacteria. Ba et al. (2008) showed that NDF digestibility decreased linearly when growing Laisind cattle were fed on increasing levels of CRM (ranging from 0.3 to 2.0 % of BW).

Conclusion

There was a reduced URTRS intake and no improved LWG when cattle were supplemented with 1,000 g compared to 300 g CRM in the diets without GNC. The combination of 1,000 g CRM and 700 g GNC significantly increased LWG and tended to improve URTRS intake and OM digestibility, reducing the FCR and feed cost.

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Conflict of interest The authors declare that they have no conflict of interest.

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Paper III

Varying supplemental cassava root meal without or with groundnut cake during growing phase impacts performance, carcass characteristics and meat quality of finished Laisind cattle.

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Abstract

The objectives of experiment were to determine the effects of supplemental strategies during growing phase on performance, carcass characteristics and meat quality of finished Laisind cattle. Twenty-four crossbred Laisind male cattle (50% Red Sindhy x 50% local Yellow), from 18 to 21 months of age, were used in the experiment. Before entering the finishing period, animals were raised under different supplemental regimes, supplemented with 0.3 or 1.0 kg cassava root meal (CRM) and without or with 0.7 kg groundnut cake (GNC), and gained 0.28, 0.31, 0.35 and 0.54 kg per day. The finishing phase lasted 105 day including 14 days adaptation. Animals received concentrate at 1.5 percent of body weight (BW) and urea treated rice straw (URTRS) *ad libitum* until slaughter (around 310 kg BW). Levels of concentrate offered were adjusted every two weeks according to BW. All cattle were slaughtered after the finishing period to assess carcass and meat quality. Cattle offered high level of CRM and GNC during growing phase had lower LWG and higher feed conversion ratio (FCR), but had highest carcass weight, trimmed fat, edible meat and intramuscular fat (IMF) content compared to the rest. It is concluded that preparing cattle for finishing phase should be supplemented with high CRM and GNC during growing phase in order to increase IMF content, carcass weight and edible meat of finished cattle.

Introduction

In Vietnam, beef originate from intact young bulls, heifers and culled animals. The beef is tough (Luc *et al.*, 2009) because of their age at slaughter and almost cattle enter domestic markets without previous fattening. However, the demand markets of beef meat and beef of high quality has been increasing. In 2013 Vietnam imported 66,951 beef cattle from Australia for consumption (Beef Central, 2014). Several studies showed that fattened cattle had higher carcass weight and meat quality than those without fattening (Vestergaard *et al.*, 2007; Minchin *et al.*, 2010; Therkildsen *et al.*, 2011). A finishing period is necessary for optimum beef quality and quantity before entering market.

Live weight gain (LWG) during the growing period may affect carcass yield, meat quality and feed efficiency utilization during the finishing period. It has been shown that increased LWG during growing phase and finishing increases intramuscular fat, carcass fatness (Vestergaard *et al.*, 2000; Robinson *et al.*, 2001) and improves the tenderness, juiciness and flavor of beef (Perry and Thompson, 2005; Lawrie and Ledward, 2006). However, excessive fat accumulation decreases the efficiency of feed utilization (Murphy and Loerch, 1994). Though, low LWG during growth phase had *Longissimus dorsi* area higher than those gave higher LWG (Sharman *et al.*, 2013; Exp. 2). Other studies reported there were no difference in carcass and meat quality at slaughter (Loken *et al.*, 2009; Blanco *et al.*, 2012) LWG and feed efficiency utilization (Hersom *et al.*, 2004) between low and high LWG during growing phase when they were on the same diet during finishing phase.

Cattle are generally fed on rice straw-based diets during the drought seasons in Vietnam. Rice straw (RS) is low in nutritive value and poor in digestibility. Urea treatment improves RS quality and currently seems to be practical for on-farm use (Sarnklong *et al.*, 2010). Cattle were also supplemented with some locally available feeds such as cassava root meal (CRM), groundnut cake (GNC) but the amounts of supplementary feeds vary a lot among farms. Thus, there were variations in LWG of cattle before entering the finishing regime thereafter dry season. Supplementation of fish meal and/or soybean meal (Nhiem *et al.*, 2013), and of high levels of CRM in combination with GNC (Trung *et al.*, 2014) improved LWG of cattle fed on urea treated rice straw (URTRS) basal diets. However, the feed availability and lack of money limits increasing quantity of supplementary feeds in many smallholders during dry season. Alternatively, it is possible to maintain only a low growth rate through this period while waiting for the next season and take advantage of compensatory growth from finishing on concentrate-based diets. Therefore, the objectives of this experiment are to determine the effect of supplementary strategies during growing phase on performance, carcass characteristics and meat quality of finished Laisind cattle.

Materials and methods

The study was conducted from March 2009 to April 2010 at the Bavi Forage and Cattle Research Centre in northern Vietnam. The climate is tropical monsoon with a wet season between April and November and a dry season from December to March.

Experimental feed preparation

The basal diets used in the experiment included urea treated rice straw (URTRS) fed *ad libitum* and concentrate at 1.5 percentage of body weight (BW). Urea treatment was achieved by spraying an aqueous solution containing urea (40 g/kg) and water (800 g/kg) on the basis of the air-dry weight of rice straw (91% dry matter) in the container, and was then sealed up for a minimum 3 weeks before feeding directly to animals. The concentrate included maize, CRM, soybean meal, fish meal, urea, trace mineral-vitamin premix, bone meal and common salt; all feed ingredients were purchased from the local market. The chemical composition and estimated metabolizable energy (ME) of experimental feeds are shown in Table 1.

Animals, experimental design and management

Twenty-four crossbred Laisind male cattle (50% Red Sindhy x 50% local Yellow), from 18 to 21 months of age, were used in the experiment. Before entering the finishing period, cattle were raised under different supplemental regimes containing varying levels of CRM and GNC in addition to 2.0 kg of corn silage and URTRS *ad libitum*. The growing period lasted for 98 days, during which cattle gained 0.28, 0.31, 0.35 and 0.54 kg per day. Further results are present in the paper of Trung *et al.* (2014). The animals were then assigned to finishing period. During this period, all animals were given the same diet, URTRS *ad libitum* plus concentrate. Levels of concentrate offered were adjusted every two weeks according to BW. The animals were housed in individual pens with individual feeder and had free access to water.

The concentrate was divided equally two times daily, in the morning at 7 a.m. and at 5 p.m. Cattle were offered URTRS twice a day, after cattle feeding concentrate in the morning and at the 6 p.m. The total amounts of URTRS offered were 25% in excess of the previous day's intake. The finishing period lasted for 105 days, including 14 days for adaptation.

During the adaptation period, the amount of concentrate was gradually increased during a 2-wk period to achieve the 1.5% of BW. The composition of concentrate is presented in Table 2.

Feed offered and refusals were recorded daily during the finishing experiment. Refusals were removed and weighed before the morning feeding. Samples of feeds offered and refusals were taken twice a week and cattle were weighed weekly.

Carcass evaluation

After finishing the fattening period, all cattle were slaughtered in two consecutive days to determine carcass characteristics such as warm carcass weight, dressing percent, edible meat, trimmed fat and bone. All animals were stunned and bled. The carcass was split into two halves and each half was weighed. The left side was deboned and the bone, lean meat and trimmed fat were separated manually and weighed.

The *m. longissimus dorsi* (LD) from the both sides, between the first and the thirteenth ribs, was removed separately from each carcass. Approximately two kg of LD, from the sixth to ninth rib on the right side of each carcass, was sampled and stored at a temperature not higher than 4°C for 12 h. The sample was then cut into 2.5 cm thick pieces, wrapped in polyethylene bags and stored at a temperature not higher than 4°C for analyses of muscle pH at 1 h and 48 h, color, drip loss, and cooking loss at 48 h, and shear force value at 48 h and 8 days *post mortem* following a protocol described by Cabaraux *et al.* (2004).

The pH was measured by using pH meter Testo 230. The average pH value was calculated from measurements repeated six times on different points of the sample. Minolta CR-410 was used to measure meat color on raw meat according to CIE L*a*b*system. The L*, a* and b* represent the lightness (0 = black, 100 = white), redness (lower number = more green i.e. less red, higher numbers = more red i.e. less green; measurement range = -60 to 60), and yellowness (lower numbers = more blue i.e. less yellow, higher numbers = more yellow i.e. less blue; measurement range = -60 to 60), respectively. Five repeated measurements of color were taken on the surface of each muscle sample. The drip loss was calculated as percentage of the weight change before and after storing. The LD cuts were cooked in a plastic bag in a waterbath (Mettler) for 50 min at 75°C. After cooking, these cuts were cooled in cold tap water down to ambient temperature, then the bags were drained and the surface of cuts was dried with tissue paper. The cooking loss was calculated based

on weights before and after cooking. The toughness was estimated by measurement of the Warner Bratzler peak shear force with a Warner Bratzler 2000D perpendicular to the fiber direction on five 1.25-cm-diameter cores obtained from the heated cuts.

Chemical analysis

Samples of feeds and refusals were analyzed for dry matter (DM), ash, crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), and acid detergent fiber (ADF). The DM (ID 930.15), CP (ID 976.05), and ash (ID 942.05) were analyzed according to the standard methods of AOAC (1990). The EE was analyzed by ISO (6492:1999) and NDF and ADF concentrations were determined according to the procedure of Van Soest *et al.* (1991). The samples of *m. longissimus dorsi* were analyzed for dry matter (DM), ether extract (EE), moisture and crude protein according to AOAC (1990). The ME content of feeds were estimated using the *in vitro* gas method and the equations proposed by Menke and Steingass (1988), respectively for roughages and concentrates as:

$$ME_{\text{roughages}} \text{ (MJ/kg DM)} = 2.2 + 0.1357 \times \text{GP24} + 0.0057 \times \text{CP} + 0.0002859 \times \text{EE}^2$$

$$ME_{\text{concentrates}} \text{ (MJ/kg DM)} = 1.06 + 0.157 \times \text{GP24} + 0.0084 \times \text{CP} + 0.022 \times \text{EE} - 0.0081 \times \text{ash.}$$

Where GP24 (ml/200mg of DM incubated) was the gas production measured at 24h; CP and EE as g/kg DM.

Statistical analysis

The data were analyzed statistically by Analysis of variance (ANOVA) using the General Linear Model least squares procedures of Statistical Analysis Systems Institute (SAS, 1996). The statistical model used was $Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \gamma_k + \varepsilon_{ijk}$ where: Y_{ijk} is the dependent variable, μ is the overall mean, α_i is the effect of CRM level i , β_j is the effect of the GNC level j , $(\alpha\beta)_{ij}$ is the effect of interaction of CRM and GNC, γ_k is the effect of the k_{th} block, and ε_{ijk} is the random error. When the treatment least square means showed a significant difference at $P \leq 0.05$, Tukey's procedure was applied for pairwise comparison of means.

Results and discussion

There was no difference in intake of URTRS, total-diet DM, ME and CP between groups of cattle (Table 3). These results were consistent with findings of Loken *et al.* (2009), low and high LWG during the growing period had similar DM intake during finishing phase. These results were due to live weight of cattle was not large difference enough and there were no restricted feeding cattle during the growth period.

A significant crossing-over effect of protein level was observed in daily gain (Table 3). On average, cattle offered the non GNC diet during the growing phase had a significantly higher LWG compared to cattle offered GNC (1.06 *versus* 0.95 g/d, $P < 0.01$). Similarly, Robinson *et al.* (2001) noted that cattle supplemented with high protein pellets during growing phase had lower LWG in the fattening period. Schoonmaker *et al.* (2004) showed that lower growth rate during growing phase gave higher LWG during finishing period compared to those having high LWG during growing phase. Neel *et al.* (2007) reported that cattle fed to achieve a low daily gain during winter had the greatest LWG during the finishing period, whereas cattle fed to achieve a high daily gain had the lowest LWG during the finishing period. There were no carry-over effects of CRM supplementation in the growing phase on LWG in the finishing period (Table 3). Loken *et al.* (2009) observed that feeding steers diets that differ in energy concentration and result in LWG of 1.4 and 1.7 kg/d during the growing period had no difference in LWG during finishing phase.

Supplementing 700g GNC resulted in cattle having higher FCR_{DM} compared to those offered without GNC (7.6 *versus* 6.7 kg DM/kg LWG, $P < 0.001$) (Table 3). Increased feed intakes and better feed conversion were found for finishing steers backgrounded on a low energy hay diet when compared with finishing cattle fed a high-energy diet during the growing phase (Merchen *et al.*, 1987). Cattle offered 1000g CRM during the growing period had a significant higher feed conversion ratio (FCR_{DM}) compared to those offered 300g CRM (7.5 *versus* 6.8 kg DM/kg LWG, $P < 0.001$). McGregor *et al.* (2012) showed that no improvement in FCR_{DM} was observed for fattened steers that were limit-fed grain or backgrounded on alfalfa haylage compared to those fed *ad libitum* grain during backgrounding.

There was significant interaction between supplemental CRM and GNC during growing phase on warm carcass weight ($P < 0.01$) such as higher CRM increased warm carcass weight compared to lower CRM level on the GNC diets. Blanco *et al.* (2012) reported that even the finishing weight was not significant different between supplemented and unsupplemented

cattle, the cattle supplemented with concentrate during winter period had higher warm carcass weight and dressing percent compared to those fed on unsupplemented diets during winter. Keane and Drennan (2009) showed that the winter diet increased carcass weight but not dressing percentage. Dressing percent of finishing Laisind cattle in the current study was higher than those achieved in finished Laisind cattle in a previous study (Nhiem, 2012), who reported that finished Laisind cattle had dressing percent of 48.33. This difference may be due to the final live weight in the present study which were ranging from 303 to 315kg compared to around 274kg in the experiment by Nhiem (2012). Vestergaard *et al.* (2007) showed that fattened cattle having higher live weight at slaughter had higher dressing percent compared to those having lower live weight. Edible meat of cattle supplemented high CRM and GNC had higher than those fed on high CRM without GNC during growing period ($P < 0.05$) (Table 4); this was attributed to difference in carcass weight. There was a carry-over effect of level of both CRM as well as GNC on the fat contents (trimmed fat) of carcass (Table 4). Finished cattle supplemented with high CRM level during growing phase had higher trimmed fat compared to those fed on low CRM level (6.7 *versus* 6.1; $P < 0.01$). Supplementation of GNC during growing period resulted in cattle having higher trimmed fat compared the cattle fed on without GNC diets (6.75 *versus* 6.0; $P < 0.001$). Therkildsen *et al.* (1998) observed that cattle having higher LWG during growing phase had higher fat cover (EUROP fatness) compared to those were low LWG. Another reason could be due to increased warm carcass weight resulted in increased trimmed fat, which is consistence with previous results of Nhiem (2012) in Laisind cattle. The higher trimmed fat in the present study partly explained the lower FCR_{ME} for increasing LWG.

Meat color values in the study were comparable to values of Laisind cattle produced in Vietnam (Hue *et al.*, 2008; Luc *et al.*, 2009; Nhiem, 2012). There was no difference in L^* and a^* between groups (Table 5), which is in agreement with McGregor *et al.* (2012); previous feeding regimes had no effects on color values of finishing cattle. No carry-over effects of supplemental regimes during growing period were found in the shear force value (Table 5), with slightly lower value compared to those values reported by Nhiem (2012) in Laisind cattle slaughtered at a lower weight (270 kg). Vestergaard *et al.* (2000) also reported that difference in LWG during growing phase had no effects on the shear force value of finished cattle.

Supplementation with the higher level of CRM or GNC during the growing phase increased lipid concentration (intramuscular fat) of finished cattle (Table 5). This could be

due to difference in growth rate during the growing phase and/or different slaughter weight. Steers with better nutrition during growing phase tended to have more intramuscular fat (IMF) content compared to those on lower nutrition after fattening (Robinson *et al.*, 2001). Vestergaard *et al.* (2000) noted that IMF of m. *longissimus dorsi* was higher when the young bulls had been fed *ad libitum* than when they were fed restrictive or compensatorily. Reduced growth rate during backgrounding tends to be associated with a reduction in the IMF contents of steers, despite the steers exhibiting compensatory growth during finishing (Pethick *et al.*, 2004). Nhiem (2012) reported that increasing slaughter weight partly resulted in increased lipid contents. Marbling scores increased linearly with warm carcass weight (Bruns *et al.*, 2004). However, slaughter weight had no effects on IMF of crossbred Brahman and Charolais with Thai native cattle (Waritthitham *et al.*, 2010). Sharman *et al.* (2013; Exp. 2) indicated that marbling score increased as slaughter weight increased after growing phase, and there was no difference in marbling score after finishing.

Conclusion

Varying supplementation strategies during growing phase affect subsequent growth rate, efficiency of feed utilization, carcass weight, edible meat and intramuscular fat. Cattle offered 1000g CRM and 700g GNC during growing phase had highest carcass weight, edible meat, trimmed fat and intramuscular fat compared to the rest.

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Table 1. Chemical composition and estimated metabolizable energy (ME) content of experimental feeds (Mean and S.D.).

Item	Maize	CRM	Soybean cake	Fish meal	Urea	URTRS
DM, g/kg	910.8(9.6)	892.4(18.4)	907.4(14.7)	909.3(13.2)	900.0	447.1(28.0)
In g/kg DM						
OM	963.6(5.9)	973.6(7.9)	924.2(8.9)	745.9(6.8)	NA	846.2(17.0)
CP	105.9(10.1)	24.6(6.5)	501.0(12.1)	512.3(11.4)	287	105.0(11.7)
EE	108.1(10.61)	11.8(5.4)	21.2(6.5)	102.4(9.7)	NA	8.0(2.7)
NDF	304.3(9.8)	72.7(16.2)	143.9(11.7)	NA	NA	683.3(27.9)
ADF	68.4(11.0)	46.8(10.2)	46.6(9.6)	NA	NA	414.5(29.2)
Ash	36.4(5.9)	26.4(7.9)	75.8(8.9)	254.1(6.8)	NA	153.8(17.0)
ME, MJ/kg DM	11.0(0.4)	12.2(0.2)	12.5(0.5)	10.6(0.4)	NA	5.4(0.3)

CRM cassava root meal; *URTRS* urea treated rice straw; *DM* dry matter; *OM* organic matter; *CP* crude protein; *EE* ether extract; *NDF* neutral detergent fiber; *ADF* acid detergent fiber; *ME* metabolizable energy; *MJ* mega joule; *NA* not analyzed

Table 2. The composition of the concentrate (air-dry basis)

Ingredient	Percentage
Maize	61.5
Cassava root meal	15.0
Soybean cake	13.0
Fish meal	5.0
Urea	1.5
Trace mineral & vitamin premix ^a	1.0
Bone meal	2.0
Salt	1.0
ME (MJ/kg DM)	10.8
CP (%)	20.2

ME metabolizable energy; *MJ* mega joule; *DM* dry matter; *CP* crude protein

^a Elements on % basic as guaranteed by the manufacturer; Fe: 0.5, Mg: 0.7, Mn: 1.0, Zn: 0.2, Cu: 0.1, K: 0.02, Na: 1.5, I: 0.001, Se: 0.001. Vitamins (per 1000g): Vitamin A: 2,000,000 IU, Vitamin D3: 400,000 IU, Vitamin E: 600 mg, Vitamin K3: 200mg, Vitamin B1: 200mg, Vitamin B2: 1000mg, Vitamin PP: 1500mg, Ca pantothenat: 500mg, Cholin chloride: 10,000mg.

Table 3. Feed intake, live weights gain (LWG) and feed conversion ratio (FCR) of finished Laisind cattle. Least square means and standard error of mean (SEM).

	Treatment during growing period				SEM	Significance		
	0	0	700	700		CRM	GNC	CRM*GNC
GNC, g/d								
CRM, g/d	300	1000	300	1000				
DMI, % of BW								
URTRS, % of BW	1.36	1.41	1.43	1.42	0.04	NS	NS	NS
Concentrate, % of BW	1.42	1.43	1.38	1.34	0.03	-	-	-
Total-diet DMI, % of BW	2.79	2.81	2.75	2.74	0.04	NS	NS	NS
Nutrient intake								
ME, MJ/d	57.9	57.3	56.1	59.0	1.14	NS	NS	NS
CP, kg/d	1.10	1.07	1.07	1.12	0.03	NS	NS	NS
Initial weight, kg	197 ^b	202 ^b	198 ^b	221 ^a	1.9	-	-	-
Final weight, kg	309	304	303	315	4.2	NS	NS	0.06
LWG, kg/d	1.08 ^a	1.00 ^{ab}	0.95 ^{ab}	0.90 ^b	0.037	NS	**	NS
FCR _{DM}	6.5 ^c	6.9 ^{bc}	7.1 ^b	8.1 ^a	0.1	***	***	0.06
FCR _{ME}	53.6 ^c	57.4 ^{bc}	59.2 ^b	64.8 ^a	1.34	**	***	NS
PER	1.01 ^c	1.08 ^{bc}	1.12 ^b	1.23 ^a	0.025	**	***	NS

^{a,b,c}Mean within rows with different superscripts are significantly different (P<0.05)

GNC groundnut cake; CRM cassava root meal; DMI dry matter intake; BW body weight; URTRS urea treated rice straw; ME metabolizable energy; MJ mega joule; CP crude protein; LWG live weight gain; FCR_{DM} feed conversion ratio (kg DM/kg LWG); FCR_{ME} feed conversion ratio (MJ ME/kg LWG); PER protein efficiency ratio (kg CP/kg LWG)

* P<0.05; ** P<0.01; *** P<0.001; NS: none significant.

Table 4. Mean carcass yield of finished Laisind cattle. Least square means and standard error of mean (SEM).

GNC, g/d	Treatment during growing period				SEM	Significance		
	0	0	700	700		CRM	GNC	CRM*GNC
CRM, g/d	300	1000	300	1000				
Warm carcass weight (kg)	152.1 ^{ab}	148.1 ^b	149.1 ^b	157.3 ^a	1.55	NS	NS	**
Dressing percentage (%)	49.2	49.0	49.7	49.9	0.53	NS	NS	NS
Edible meat (kg)	123.1 ^{ab}	118.8 ^b	120.4 ^{ab}	125.9 ^a	1.56	NS	NS	*
Edible meat (%)	81.0	80.5	80.9	80.2	0.35	NS	NS	NS
Trimmed fat (%)	5.8 ^b	6.2 ^b	6.3 ^b	7.2 ^a	0.17	**	***	NS
Bone (%)	13.3	13.7	13.1	12.8	0.33	NS	NS	NS

GNC groundnut cake; CRM cassava root meal

* P<0.05; ** P<0.01; *** P<0.001; NS: none significant.

Table 5. Meat quality and *m. longissimus dorsi* chemical composition of finished Laisind cattle. Least square means and standard error of mean (SEM).

	Treatment during growing period				SEM	Significance		
	0		700			CRM	GNC	CRM*GNC
GNC, g/d	0	0	700	700				
CRM, g/d	300	1000	300	1000				
Meat color								
Lightness (L*)	37.6	37.1	37.2	38.1	0.53	NS	NS	NS
Redness (a*)	19.3	19.4	19.1	18.7	0.38	NS	NS	NS
Yellowness (b*)	6.70	6.77	6.86	7.20	0.271	NS	NS	NS
pH _{1h}	6.67	6.65	6.70	6.61	0.034	NS	NS	NS
pH _{48h}	5.29	5.30	5.32	5.31	0.033	NS	NS	NS
Drip loss, %	1.75	1.68	1.63	1.41	0.091	NS	NS	NS
Cooking loss, %	34.5	32.8	33.6	32.1	0.98	NS	NS	NS
Shear force value, N								
48h	79.3	78.0	82.0	77.3	2.90	NS	NS	NS
8 days	65.2	63.6	64.3	62.5	3.01	NS	NS	NS
<i>M. longissimus dorsi</i> chemical composition, %								
Moisture	75.8	75.9	75.9	75.3	0.3	NS	NS	NS
Protein	21.7	21.6	21.5	21.8	0.29	NS	NS	NS
Lipid	0.86 ^b	0.95 ^b	1.04 ^{ab}	1.28 ^a	0.075	*	**	NS
Ash	1.59	1.61	1.57	1.60	0.028	NS	NS	NS

GNC groundnut cake; CRM cassava root meal; N newton

* P<0.05; ** P<0.01; *** P<0.001; NS: none significant.