THESIS APPROVAL

GRADUATE SCHOOL, KASETSART UNIVERSITY

Master of Science (Animal Nutrition and Feed Technology)
DEGREE

Animal Nutrition and Feed Technology — **FIELD**

Animal Science — **PROGRAM**

TITLE: Effects of Dietary Energy Sources and Protein Levels on Performance, Carcass Quality and Production Cost of KamphaengSaen Beef Cattle

NAME: Mr. NannWinn Soe

THIS THESIS HAS BEEN ACCEPTED BY

.... **THESIS ADVISOR**

(Associate Professor SuriyaSawanon, Ph. D. **)**

.... **DEPARTMENT HEAD**

(Associate Professor NeramitSookmanee, Ph. D. **)**

APPROVED BY THE GRADUATE SCHOOL ON ....

.... **DEAN**

(Associate Professor GunjanaTheeragool, D.Agr. **)**

THESIS

EFFECTS OF DIETARY ENERGY SOURCES AND PROTEIN LEVELS ON PERFORMANCE, CARCASS QUALITY AND PRODUCTION COST OF KAMPHAENG SAEN BEEF CATTLE

NANN WINN SOE

A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
Master of Science (Regular Program)
Graduate School, Kasetsart University
2013

Nann Winn Soe 2013: Effects of Dietary Energy Sources and Protein Levels on Performance, Carcass Quality and Production Cost of Kamphaeng Saen Beef Cattle. Master of Science (Animal Nutrition and Feed Technology), Major Field: Animal Nutrition and Feed Technology, Department of Animal Science. Thesis Advisor: Associate Professor Suriya Sawanon, Ph. D. 92 pages.

Two experiments were carried out to study the effect of dietary energy sources and protein levels on performance, carcass quality and production cost of Kamphaeng Saen beef cattle. In the first experiment, sixteen Kamphaeng Saen young bulls (initial body weight 212.81 ± 29.79 kg) were used to study the effect of concentrate feeding levels with different crude protein (CP) levels. The young bulls were fed *ad libitum* access to para grass (*Brachiaria mutica*). Two factors; concentrate feeding level (1.0 and 1.5 % BW) and CP level (14 and 16 % CP) were used according to 2×2 factorial in Complete Randomized Design (CRD) with an initial BW covariate. The results showed there was no significant interaction between two factors. Higher concentrate feeding level (1.5 % BW) showed a significantly increase ($P < 0.05$) in weight gain (WG), average daily gain (ADG), feed conversion ratio (FCR) and dry matter intake (DMI). However, increasing the CP levels had no effects on growing performance and DMI. Although total feed cost was higher in 1.5% BW concentrate feeding group than 1.0%, total feed cost per gain was not much different (28.26, 30.35 baht) between two concentrate feeding levels. Proper level of supplementary concentrate feeding could be efficaciously utilized by growing cattle fed on low-quality grass.

The second experiment was started soon after the first experiment was done by using the same cattle from the first experiment. 2×2 Factorial in Randomized Complete Block Design (RCBD) with two factors; different energy sources cassava chip (c) and cassava chip plus ground corn (cc) and different crude protein levels (12 and 14 % CP) were used to study the effects on the performances, carcass quality and production cost of 24 finishing Kamphaeng Saen beef steers. The results showed that cTMR feeding had better finishing performance (final BW 514.00 > 493.75 kg), higher income (carcass income 46,964 > 44,122 baht) and cheaper price (feed price 7.52 < 7.60 baht/kg) than that of ccTMR feeding without affecting on meat quality. TMR with the 14% CP has enough potential to show higher finishing weight (final BW 514.25 > 493.50 kg) and carcass weight (WCW 293.29 > 281.79 kg and CCW 291.29 > 278.22 kg) but higher feed cost (total feed cost 9,138.30 > 8,586.90 baht per head and total production cost 41,868.30 > 40,636.90 baht per head) than 12 % CP. However, feed cost per gain was no difference and profit tended to be higher in 14 % CP feeding group. Nevertheless, cassava chip has enough potential to be used as an energy source in TMR for feedlot cattle because of its cheaper price and market availability.

___________________________ ___________________________ ___ / ___ / ___

Student's signature Thesis Advisor's signature

ACKNOWLEDGEMENTS

First of all, I would like to express my deepest appreciation, gratitude and respect to Assoc. Prof. Dr. Suriya Sawanon, my academic advisor and chairman of my thesis advisory committee, for his invaluable advices, comments, suggestion, encouragement and guidance in the whole process of the study that enable me to complete this thesis while I was studying and conducting my research at Kasetsart University, Kamphaeng Saen campus.

My special thanks go to the Thailand International Development Cooperation Agency (TICA), Ministry of Livestock and Fisheries, Myanmar for providing a scholarship of this study. I would also like to thank Buffalo and Beef Production Research and Development Center and Animal Produce Research and Development Center, Kasetsart University, Kamphaeng Saen Campus for supporting my research.

I would like to express my special gratitude to Head of Department, Assoc. Prof. Dr. Neramit Sookmanee, all professors, teachers, students and staff members in Department of Animal Science, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Kamphaeng Saen Campus, for their helps. Special thanks to Mr. Phoompong Boonsaen, Ms. Sutisa Majarune, Mr. Wisut Maitreejet and Mr. Somporn Poonko for their kind helps and friendly explanations about the experiment works. I would like to extend my great thanks to U Myo Thet Shwe (Managing Director of LFME) and Dr. Pyae Sone (General Manager of LFME) for their nomination for this study.

Finally, I wish to express my enormous thanks to my father U Phone and my mother Daw Aung May and my family who are my source of inspiration, encouragement and dedication to complete my study at Kasetsart University, Kamphaeng Saen Campus, Thailand.

Nann Winn Soe
May, 2013

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

Figure **Page**

Appendix figure

LIST OF ABBREVIATIONS

ADG	=	average daily gain
AF	=	proportion of empty body fat
ANOVA	=	analysis of variance
ASAEN	=	association of Southeast Asian nations
ATP	=	adenosine tri-phosphate
BRDC	=	buffalo and beef production research and development center
BW	=	body weight
Ca	=	calcium
CCW	=	chilled carcass weight
CNGs	=	cyanogenic glucoside
Co	=	cobalt
CP	=	crude protein
Cu	=	copper
DE	=	digestible energy
DFD	=	dark, firm, and dry appearance
DIP	=	degradable intake protein
DM	=	dry matter
DMRT	=	Duncan's new multiple range test
DMI	=	dry matter intake
DOMI	=	digestible organic matter intake
FCR	=	feed conversion ratio
Fe	=	iron
GE	=	gross energy
HCN	=	hydrogen cyanide
WCW	=	warm carcass weight
I	=	iodine
K	=	potassium
KPH	=	kidney, pelvic and heart fat
LD	=	*Longissimus dorsi* muscle

LIST OF ABBREVIATIONS (Continued)

MCP	=	microbial protein
ME	=	metabolizable energy
Mg	=	magnesium
Mn	=	manganese
mt	=	metric ton
N	=	nitrogen
Na	=	sodium
NDF	=	neutral detergent fiber
NE	=	net energy
NEg	=	net energy gain
NEm	=	net energy maintenance
NFC	=	non-fiber carbohydrates
NFE	=	nitrogen-free extract
NH3	=	ammonia
NPN	=	non-protein nitrogen
OM	=	organic matter
P	=	phosphorus
pHu	=	ultimate pH
PSE	=	pale, soft and exudative appearance
RDP	=	rumen degradable protein
RUIP	=	rumen undegradable intake protein
S	=	sulfur
Se	=	selenium
SEM	=	standard error of the mean
TDN	=	total digestible nutrient
TMR	=	total mixed ration
VFA	=	volatile fatty acids
WHC	=	water holding capacity
WBSF	=	Warner-Bratzler shear force
Zn	=	zinc

EFFECTS OF DIETARY ENERGY SOURCES AND PROTEIN LEVELS ON PERFORMANCE, CARCASS QUALITY AND PRODUCTION COST OF KAMPHAENG SAEN BEEF CATTLE

INTRODUCTION

In most Southeast Asian countries, cattle are raised in rural area for their agricultural uses by means of providing draught power, meat, manure, hide and milk. Cattle production in such developing countries was highly depended on pastures, crop residues and certain poor forages. Rearing indigenous beef cattle breeds on natural pasture without dietary supplementation in communal areas is a common feature in developing countries. Consequently, the beef quality from such small scale production is poor and cheap in price. Nowadays, new technologies, mechanization, modernization are changing agricultural production systems from traditional to mechanical system and making reduction in cattle production of the rural areas. With increasing in population in Southeast Asian countries and decreasing in cattle production, beef market demand is rising day by day. Moreover, beef cattle production cannot reach the market demand by using indigenous beef cattle breeds and natural pasture.

Quality beef production in Thailand have been started to supply the tourist market by using a crossbred Charolais or any European breeds (Laorodphan *et al.*, 2012). Kamphaeng Saen beef cattle is the first Thai beef cross-breed between *Bos Taurus* (50% Charolais) and *Bos indicus* (25% Brahman and 25% Thai native). As the cattle was designed to give faster growth rates and better performance, it is important to provide the cattle with adequate amounts of digestible nutrients for their optimal performance. Otherwise, the predominantly use of low nutritive value forage will usually result with poor performance and reduce average daily gain (ADG 450 g/d) (Sawanon, 2003). Therefore, additional protein and energy supplement will be often required for the cattle fed on forage-based diets as forages quality is low during the winter season or under a poor management (Horrocks and Vallentine, 1999). Energy and protein sources are the most important nutrients for beef cattle as the nutrients stimulate rumen micro-organisms for their growth and rumen fermentation and enhance the productive functions of the animals. Therefore, we should understand that how much concentrate we should supply? What types of energy sources we should use? And how many protein level we should use with those diets?

Corn has been used as a major energy source in many different types of backgrounding and finishing diets for beef cattle nutrition. In recent years, the production and use of biofuels from cereal grains have been increasing rapidly throughout the world and there has been a rising demand for corn based ethanol. As a consequence, corn price also has been increasing. The rapid rise in grain prices was giving subsequent economic stress on the livestock industry. Moreover, the considerable increase in feed costs of those cereal grains also forced to search for cheaper energy sources for the replacement. Most researchers found that cassava can be used as an energy source at 80% in concentrate (Wanapat and Khampa, 2007) and can be replaced with corn at 30-40% in diets (Holzer *et al.*, 1997; Zinn and DePeters, 1991) without adverse effects on average daily gain or dry matter intake of feedlot cattle. Moreover, Chanjula *et al*. (2003) stated that cassava possesses a faster rate of degradability in the rumen as compared to other energy sources such as cereal grain.

In the rumen, simultaneous carbohydrate fermentation is essential for microbial protein synthesis. By using ammonia nitrogen and carbon sources from cassava chip, it is superior to other local feed energy sources (Wanapat, 2009). Using the cassava chip with ground corn will be more synchronous carbohydrate and protein degradation in the rumen when we use urea as a non-protein nitrogen (NPN) source and soybean meal. Because soy bean meal and ground corn have relatively nearly same rumen degradation rate while urea and cassava chip is highly degradable in rumen. Replacement with cassava chip 50% in diet might be better synchronization than replacing cassava chip 100%. Thus, two experiments were conducted to the Buffalo and Beef Cattle Production Research and Development Center, Kasetsart University, Kamphaeng Saen Campus to study the effects of different dietary energy sources and effects of crude protein (CP) levels on performance, carcass quality and production cost of Kamphaeng Saen beef cattle.

OBJECTIVES

The objectives of the present study were;

1. To compare the growing performance of Kamphaeng Saen young bulls by feeding different levels of supplementary concentrate (1 and 1.5 % of body weight).

2. To study the growing performance of Kamphaeng Saen young bulls by feeding different crude protein levels concentrate (14 and 16 % CP).

3. To evaluate the effect of TMR feeding with different energy sources (cassava 36 % and corn 18 % plus cassava 18 %) on the performance, carcass quality and production cost of finishing Kamphaeng Saen beef steers.

4. To determine the effect of TMR feeding with different crude protein levels (12 and 14 % CP) on the performance, carcass quality and production cost of finishing Kamphaeng Saen beef steers.

LITERATURE REVIEW

1. Prime and choice quality beef production in Thailand

There are three main types of beef production systems in Thailand based on the beef quality demanded by consumers and markets. Local quality is produced from the young bulls or retired bulls and cows culled from some farms or live cattle imported from neighbor countries (> 90% from Myanmar). Standard quality is produced from Brahman crossbred or any crossbred young bulls and the last prime and choice qualities are usually produced from *Bos Taurus* crossbred or Kamphaeng Saen steer (Yimmongkol, 2009).

Kamphaeng Saen breed is the first Thai beef cattle breed. It is a cross-breed between *Bos Taurus* (50% Charolais) and *Bos indicus* (25% Brahman and 25% Thai native) (Raungprim *et al.*, 2012). The breed was designed to give faster growth rates, better performance and quality carcass. The average standardized results on performance test from the Kamphaeng Saen breed were ADG 1.35 kg/day (min. 0.99 to max. 1.75) and FCR 5.40 (min. 4.04 to max. 7.29) respectively (BRDC, 2011).

Yimmongkol (2009) indicated that the high quality beef production in Thailand is produced by using the Kamphaeng Saen breed steers at an average of 1.5 - 2 years with an initial weight of 300 - 350 kg. They are then normally raised in feedlots and fed *ad libitum* with roughage and concentrate at a proper ratio or TMR for 8-10 months until the feedlot cattle reaches the final weight of 500 - 600 kg. Slaughtering, cutting, dressing and processing are done under food safety and traceability standards. Carcass weight ranges from 300 - 320 kg or 56 - 60% and has to be chilled for 7- 14 days or more before cutting and freezing. The carcass and meat quality are defined by age, final weight, carcass percentage, loin eye area and marbling score. Thailand produces this quality beef at 1.79 million kg/year and share 1% of beef with markets or produces from 0.01 million heads of feedlot cattle. The prime quality beef in Thailand is produced by the KU Kamphaeng Saen Campus Beef Producer Cooperative Ltd. (KU. Beef) which located at Buffalo and Beef Production

Research and Development Center (BRDC), Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom Province (Yimmongkol, 2009).

2. Energy in beef cattle

Energy is the first demand in all of animal nutrition. Carbohydrates, fats and proteins provide energy in beef cattle diets. The total energy of a feedstuff or diet (i.e., gross energy) can be determined by using bomb calorie meter method in which the sample is totally burnt and the heat produced from the burning is measured. Kilocalorie (kcal) is defined as the amount of heat necessary to raise the temperature of 1 kg of water from 15 to 16°C. Much of the energy consumed by beef cattle is wasted. Approximately 20 to 40% may be passed through the animal undigested in the feces; about 15 to 20% is lost in gases and Urine, and as much as 30% is used in producing heat in the digestive process, leaving as little as 20% for body maintenance and weight gains (Perry and Cecava, 1995). The remaining energy after subtracting the all energy losses can be utilized by the animals for their maintenance and production.

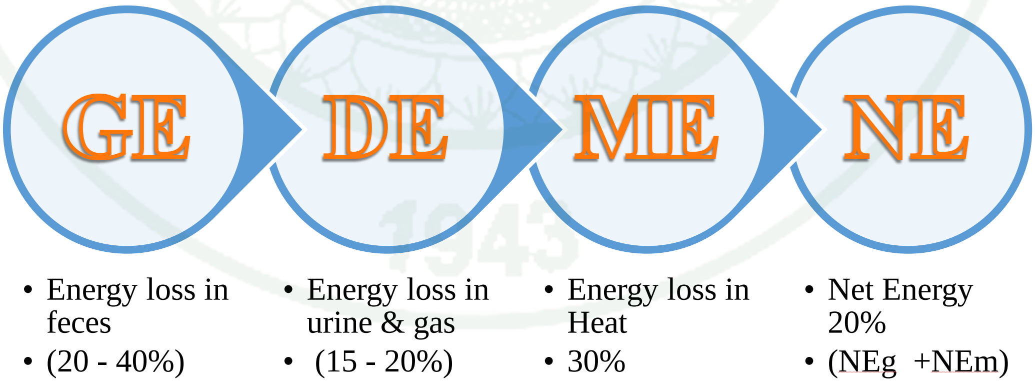


Figure 1 Energy loss and utilization by cattle

2.1. Growing period

Most of the energy input is utilized in the growth of bone and muscle in young animals so that the animals can grow larger in frame size and organs development. The muscle tissue develops rapidly in young and growing animals and makes up most of the carcass weight gain (Baker and Mikesell, 2011).

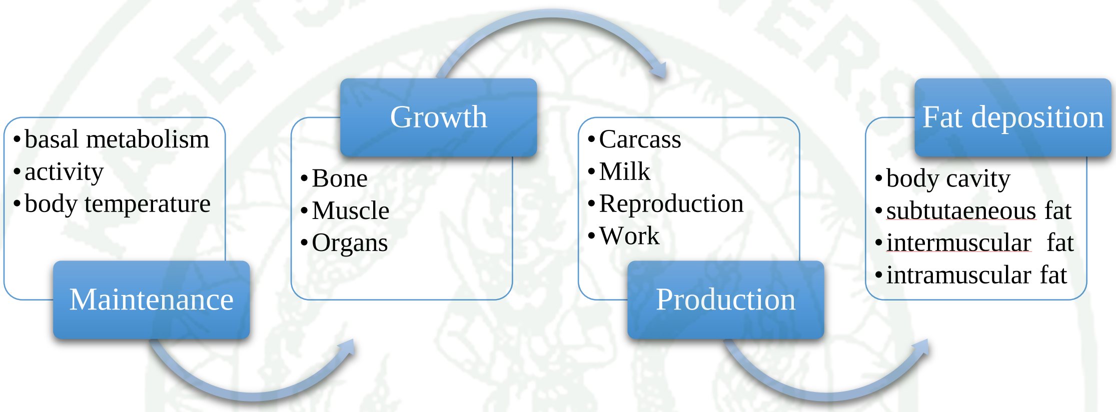


Figure 2 Energy utilization by cattle

Growth of animal will be started only after the maintenance requirements are met by utilizing nutrients in the ration. The excess feed nutrients that are not used for maintenance or growth will be stored as fat. Most of the energy from the feed will be utilized for the growth of bone and muscle while the animal was young. Growth of bones and muscles slows drastically after the animal was puberty, and the animal begins to store the energy from feed as fat in different body parts (Baker and Mikesell, 2011).

2.2. Finishing period

The rate of muscle growth becomes slow and fat deposition will increase as the animal grows older and larger. Firstly, fat is deposited in the body cavity of the animal and serves not only to provide energy storage but also to help cushion the internal organs. Secondly, the animal begins to deposit fat under the skin when the fat deposit in body cavity reaches its peak. Finally, fat is deposited between the muscles and in the muscles when a certain level of back fat is reached. These intermuscular fat deposits are called marbling which can flavor the meat. Totally lean meat is dry and rather tasteless. Therefore, carcass grade is largely depending upon the amount of fat which is deposited in the muscles or marbling (Herren, 2010).

2.3. Forage and concentrate feeding

The most abundant form of renewable carbohydrate resources in the world are cellulose, hemicellulose and pectin which is synthesized by plants in the process of photosynthesis. No mammalian degradative enzyme is capable of unlocking β-1,4-glucosidic linkages found in plant cell wall structural carbohydrates. However, rumen microbes can produce the enzymes which can cleave these linkages. These structural carbohydrates are occurred in all plant cell walls in association with lignin. Lignin strengthens the plant's structure and physically protects the cell-wall material from degradation by bacteria. Lignin is broken down by microbes under both aerobic and anaerobic conditions (Perry and Cecava, 1995).

Cattle have the ability to utilize large amount of roughage because of the anaerobic microorganisms dwelling in the rumen. Therefore, cattle can thrive primarily on forages and roughages as sources of energy and nutrients. However, additional protein and energy supplement will be often required for the cattle fed on forage-based diets as forages quality is low during the winter season or under a poor management (Horrocks and Vallentine, 1999). Low-quality forages are typically high in fiber and low in protein as well as low in metabolizable energy concentration and providing supplemental energy to grazing ruminants often improves production (Caton and Dhuyvetter, 1997).

Ovenell *et al.* (1991) reported feeding the proper amounts of supplements improved utilization of low-quality forage. Supplementation can positively or negatively affect forage digestion depending on the source of supplemental energy (Grigsby *et al.*, 1993) and level of feeding (Pordomingo *et al.*, 1991). Marino *et al.* (2006) also reported their result as animals in the high concentrate group (forage to concentrate ratio was 60 : 40) had higher weight gain than those in the lower concentrate group (forage to concentrate ratio was 70 : 30).

Increasing total DMI is one way of correcting nutrient deficiencies in livestock diets. Another concern with poor quality forages and the crude protein content of the diet is limiting dry matter intake. Generally, forage dry matter intake increases until forage CP content is about eight percent. Most diets satisfy protein requirements at 6 to 8% CP, but 9 to11% CP may be required for calves, lambs, and other herbivore offspring (Horrocks and Vallentine, 1999). Thus, if crude protein in forage crops is less than a minimum eight percent, cattle will decrease their feed intake of these poor quality forages.

There are a number of studies on the effect of concentrate feeding by feeding in different feeding levels and with different basal feed roughage; a high amount or *ad libitum* together with restricted amounts of grass or grass silage (Caplis *et al.*, 2005; Keane *et al.*, 2006; Loerch, 1990; Manninen *et al.*, 2010; Walsh *et al.*, 2008) or with poor quality forage (Arroquy *et al.*, 2004b; Baumann *et al.*, 2004; DelCurto *et al.*, 1990; Heldt *et al.*, 1999a; Klevesahl *et al.*, 2003; Marino *et al.*, 2006; Mialon *et al.*, 2008; Olson *et al.*, 1999; Robson, 1995; Sanson *et al.*, 1990) or with pasture (Pordomingo *et al.*, 1991). Most studies are based on the diets combining with a level of concentrate feeding and low quality roughage *ad libitum* or limited concentrate and different levels of roughage feeding but both high concentrate and high-digestibility grass silage *ad libitum* are not common. Studies have demonstrated that the higher levels of concentrate feeding improved animal performance (weight gain, feed conversion ratio, final weight) and also body fat score (Caplis *et al.*, 2005; Keane and Drennan, 2009; Keane *et al.*, 2006; Walsh *et al.*, 2008). On the other hand, with increasing concentrate intake, grass or grass silage intake was reduced (Caplis *et al.*, 2005) and the production of short-chain fatty acids was increased which resulted lowers rumen pH and consequently ruminal acidosis (Plaizier *et al.*, 2008). This can even generate tympany (Lowman and Lewis, 1996), and increase the incidence of laminitis and liver abscesses (Nocek, 1997). The results showed that high levels of concentrate feeding practice will leads to a high extent and rate of carbohydrate fermentation and consequently it will reduce rumen pH and increases the risk of acute acidosis. That rumen pH changes and occurring of acute acidosis is one of the major causes of reduced animal performance.

Local feed carbohydrate sources such as cereal grains, cassava, palm kernel expellers, molasses and plant proteins such as soybean meal, groundnut cake, sesame cake, leucaena are often used to supply energy and protein at lower cost per nutrient input compared with forages. Depending on the local raw feed availability and low prices of feed sources, feeding of concentrate-based diets for growing and finishing cattle is popular among beef producers. Most of the feed industries usually use a wide range of feed ingredients to make the complete commercial concentrate feeds for cattle feeding. Generally, the nutrient content and quality of these commercial feeds are questionable as compared to farm-made concentrate mixtures. The ingredients which used in farm-made concentrate are mainly based on local raw feed price, availability, palatability and feeding convenience. Therefore, the first experiment was performed to study the effect of supplementary concentrate feeding levels and different CP levels on the growing performance of the Kamphaeng Saen young bulls fed on para grass.

2.4. Corn

Corn is the most commonly used grain in beef cattle feeding. It is high in energy value and more palatable compared with all other grains. Starch is the primary energy component of corn. Corn contains high nitrogen-free extract (NFE) and nearly all of which is starch. Most of the beef cattle are finished on corn containing ration because of its palatability and high concentration of digestible energy.

Corn has been used as a major energy source in many different types of backgrounding and finishing diets and as a supplement in forage-based diets for beef cow. Although corn contains high in starch, protein content is low (NRC, 2000). Therefore, that can be negative effect for the production, especially in diets based on lower quality forages. The various levels of corn can be used in the diet of growing and finishing cattle depending on desired cattle performance. However, supplemental protein is needed in the most corn-based backgrounding and finishing diets.

Table 1 Corn production (in 1000 mt) in ASEAN 2002-2009

Country	2002	2003	2004	2005	2006	2007	2008	2009
Brunei Darussalam	0.00	0.00	0.10	0.15	0.37	0.25	0.47	0.38
Cambodia	149	315	257	248	377	523	612	924
Indonesia	9,654	9,585	11,225	12,524	11,609	13,288	16,317	17,592
Lao PDR	124	143	204	373	450	691	947	849
Malaysia	37	39	39	35	38	40	33	35
Myanmar	603	704	784	918	1,032	1,146	1,204	-
Philippines	4,319	4,616	5,413	5,253	6,082	6,737	6,928	7,034
Singapore	-	-	-	-	-	-	-	-
Thailand	4,189	4,081	4,124	4,037	3,909	3,539	4,101	4,684
Viet Nam	2,511	3,136	3,431	3,756	3,819	4,251	4,573	4,382
ASEAN	21,586	22,619	25,477	27,144	27,316	30,215	34,715	35,500

Source: ASEAN Statistical Yearbook (2010)

In recent years, the production and use of first generation biofuels have been increasing rapidly throughout the globalized world. Furthermore, a rising demand for corn based biofuels and the expansion of the biofuels industry is driving high food prices and a shortage of land for food-based agriculture in poor corners of Asia, Africa and Latin America because the raw material is grown wherever it is cheapest. The rapid rise in corn prices was giving subsequent economic stress on the livestock industry. Moreover, the considerable increase in feed costs of those cereal grains also forced to search for cheaper energy sources for the replacement.

2.5. Cassava

Cassava (*Manihotesculenta*), also called tapioca, yuca, mogo, manioc, mandioca and kamoteng kahoy originated in South America and spread over to Asia and Africa. Nowadays, cassava is extensively cultivated in 105 countries, and its edible starchy tuberous roots are used as a major energy source for human and animals. It is the third-largest source of food carbohydrates in the tropics after rice and maize and it can grow as an annual tuber crop in tropical regions and marginal soils with low organic matter, low rainfall and high temperature (Wanapat, 2003). Among ASAEN countries, Thailand is the highest cassava producer producing approximately 25 lakh metric ton per year (ASEAN, 2010).

Table 2 Cassava production (in 1000 mt) in ASEAN 2002-2009

Country	2003	2003	2004	2005	2006	2007	2008	2009
Brunei Darussalam	0.05	0.05	0.05	0.14	0.05	0.09	0.22	0.13
Cambodia	122	330	362	536	2,314	2,215	3,676	3,497
Indonesia	16,913	18,524	19,425	19,321	19,987	20,795	21,757	22,029
Lao PDR	29	150	56	51	174	233	262	153
Malaysia	34	35	38	32	32	40	35	37
Myanmar	135	138	188	202	211	282	334	-
Philippines	1,626	1,622	1,641	1,678	1,757	1,871	1,942	2,044
Singapore	-	-	-	-	-	-	-	-
Thailand	15,485	23,849	20,209	17,533	24,606	26,777	23,810	27,767
Viet Nam	4,438	5,309	5,821	6,646	7,714	7,985	9,310	8,557
ASEAN	38,782	49,957	47,740	45,999	56,795	60,198	61,126	64,084

Source: ASEAN Statistical Yearbook (2010)

The cassava root is long and tapered. The homogeneous flesh can be chalk-white or yellowish encased in a rough, brown and detachable rind outside.

Cassava roots are very rich in starch, and contain significant amounts of Ca (50 mg/100g), P (40 mg/100g) and vitamin C (25 mg/100g). However, they are poor in protein and other nutrients (Ravindran, 1992).

After harvest, the roots are sliced into chips (1 to 2 cm thick and 2 to 5 cm long) and spread out on drying pads and dried in the sun for 2 or 3 days. Cassava chip contains high level of non-structural carbohydrate and it is also highly degradable in the rumen as compared with other energy sources including corn meal (Chanjula *et al.*, 2003; Sommart *et al.*, 2000). Moreover, its cost is considerably lower than the common grains. Therefore, it has been used as readily fermentable energy source in ruminant rations (Wanapat, 2003).

Cassava contains a cyanogenic glucoside (CNGs). In plants, CNGs are stored in vacuoles and brought into contact with the hydrolyzing enzymes namely β-glucosidase and/or α-hydrocynitrilelyase excreted by bacteria and transformed into hydrogen cyanide (HCN) (Zagrobelny *et al.*, 2004). The hydrolysis of this compound yield hydrocyanic acid which is toxic to animals but has little or no effect on herbivores (Vetter, 2000). Ruminants can suffer from cyanide poisoning more than monogastrics because the hydrolytic reaction can take place in the rumen by microbial activity (Majak and Cheng, 1984). Moreover, the pH (5-6) in the rumen is optimal for the activity of the hydrolyzing enzyme β-glucosidase.

However, Holzer *et al.* (1997) stated that the CNGs content in cassava can be reduced by crushing, steam treatment, rinsing and drying. Furthermore, Thang *et al.* (2010) concluded that increasing the level of CP and metabolizable energy (ME) in the diet using cassava products improved the digestibility and growth rate of cattle fed low quality grass.

Muzanila *et al*. (2000) expressed that The dried cassava root has a high energy content due to the high content of starch which provides readily available carbohydrates for fermentation in the rumen. According to Chanjula *et al*. (2003) the starch in the cassava meal has a high degradability in the rumen which potentially facilitated the achievement of optimal energy to protein ratio. When corn was replaced with cassava up to 30-40% in diets and resulted in satisfactory animal performance and without adverse effects on average daily gain or dry matter intake of feedlot cattle (Holzer *et al.*, 1997; Zinn and DePeters, 1991). Moreover, Wanapat and Khampa (2007) stated that cassava can be replaced up to 75-80% as an energy source of concentrate diet in beef cattle.

Chanjula *et al.* (2003) stated the amount of DM and OM disappearance characteristics ranked from the highest to the lowest of degradation rate as follows: cassava chip, yellow sweet potato, purple sweet potato, white sweet potato, cassava waste, corn meal and rice bran, respectively. Cassava possesses a faster rate of degradability in the rumen as compared to other energy sources such as cereal grain. In the rumen, simultaneous carbohydrate fermentation is essential for microbial protein synthesis. By using ammonia nitrogen and carbon sources from cassava chip, it is superior to other local feed energy sources (Wanapat, 2009). Cassava chip has a high starch content (>65%) making it to be a suitable energy source combining with NPN in the feeds. Mansathit *et al*. (2012) concluded that cassava chip could be used more beneficial if it is adding urea up to 3% dry matter in concentrate diet.

3. Protein in beef cattle

A goal of ruminant protein feeding systems is to maximize the conversion of ammonia to microbial proteins and to minimize ammonia loss from the rumen by absorption (Perry and Cecava, 1995). Feeding appropriate dietary CP level is crucial in the feedlot cattle nutrition. Growth performance and carcass quality can be improved by feeding adequate dietary CP level, whereas overfeeding may result nitrogen excretion into the environment (Colorado, 2013). On the other hand, DMI, ADG, FCR and carcass quality will be reduced by feeding inadequate dietary CP level (Galyean, 1996) protein deficiency can result lowered appetite, weight loss, poor growth, depressed cattle performance, and reduced production.

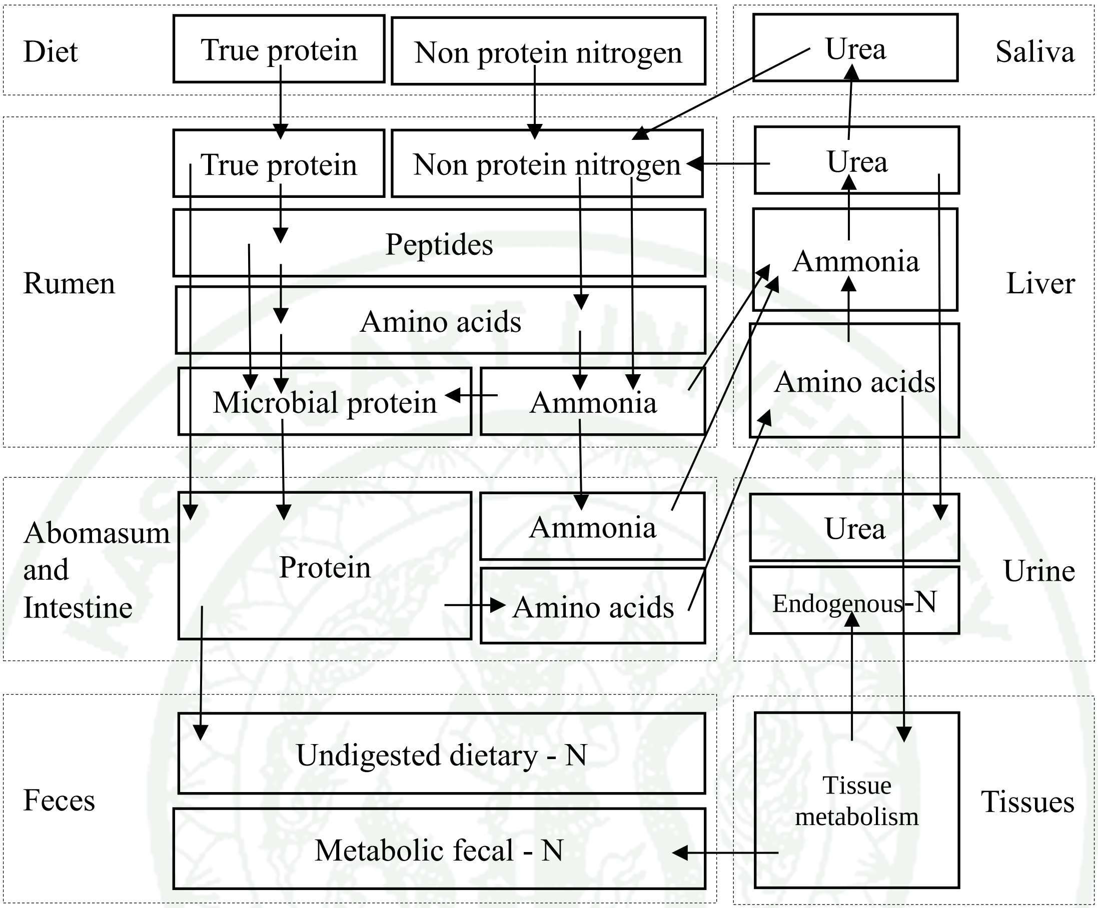


Figure 3 A model of the metabolism of nitrogen in the rumen

Source: Adapted from Perry and Cecava (1995)

Ruminant proteins digestive function before access into the small intestine varies significantly from that in the monogastric animal. Most of ingested protein sources are degraded by ruminal microorganisms to peptides and amino acids. Some of the peptides and amino acids may pass to the small intestine, where they are absorbed. However, the amino acids, in the rumen, are deaminated to form free ammonia and the carbon skeleton. Ammonia is incorporated into amino acids by using energy supply from rumen fermentation and formed into microbial protein by the ruminal microbes. Excess ammonia will be absorbed across the rumen wall into the bloodstream. Absorbed ammonia is transported to the liver where it is synthesized into urea. Urea may then (1) go to the kidneys for excretion in the urine, (2) pass into saliva and then back into the rumen. Urea which enters the rumen, either recycling via saliva or from dietary sources, is deaminated and metabolized as amino acids for microbial proteins (Perry and Cecava, 1995).

Natural protein sources such as soybean, linseed, and cotton seed meals are often used in finishing rations for beef cattle. There are several types of supplemental protein sources for beef cattle diets. The complex dynamic nature of protein nutrition in ruminants has been well established (NRC, 2000). Soybean meal with some urea is used as protein supplements in most commercial beef cattle. Urea will be rapidly degraded in the rumen by microbial digestion, and it generally works best with easily rumen degradable carbohydrate diets. If the nitrogen in urea is to be used effectively, the rumen bacteria will need sufficient energy sources available to them. In forage-based diets, urea utilization is not effective because the forage can degrade slowly in rumen. Urea feeding levels should not exceed 113 gm per day or no more than one percent of the diet in highly rumen degradable carbohydrate diets (Parish *et al.*, 2011).

Cattle protein requirements vary with size of the animal, stage of production and expected performance and meat quality. Heavier cattle typically require larger amount of crude protein intake per day than lighter cattle but as a lesser percentage of their total dry matter intake (Parish and Rhinehart, 2008). Protein requirements of cattle increase with increasing growth rate or ADG. There was observed that the more of cattle mature the less requirement of CP level as a percentage of the diet in the ration (Parish *et al*., 2011). Therefore, reducing the dietary CP percentage during the finishing period might can substitute the proper ration with appropriate price or decrease feed costs and also reduce N pollution.

When crude protein is below eight percent in forage, CP supplements are appropriate to stimulate forage intake because rumen fibrolytic bacteria cannot maintain adequate growth rates (Horrocks and Vallentine, 1999). The fibrolytic bacteria use ammonia as a chief N source (Jouany, 1991), NPN should be able to substitute for at least a portion of the degradable intake protein (DIP). Providing supplements with rumen degradable protein exerted a highly positive effect on consumption and digestion of this low-quality forage (Klevesahl *et al.*, 2003).

Baumann *et al*. (2004) concluded that digestion seemed to respond differently to ruminally degradable protein addition depending on supplemental energy source. However, substituting NPN in higher amount of the CP in such supplements has frequently resulted in poorer performance (Forero *et al.*, 1980; Rush *et al.*, 1976) and when all supplemental DIP was supplied as urea, organic matter (OM) digestion, neutral detergent fiber (NDF) digestion and digestible organic matter intake (DOMI) were lowest in the steer fed on low quality forage (Köster *et al.*, 1997). Nevertheless, for energy supplementation to be effective, RDP requirements must be met (Baumann *et al.*, 2004).

If too much urea containing diet is consumed or, if energy sources in the diet are limited then considerable amounts of ammonia will be absorbed via ruminal wall and get into the blood circulation. Most of the ammonia that entered into the bloodstream will transport to the liver to metabolize it into urea again and if ammonia level is more than the capability of the liver to eliminate it out of the body, cattle can suffer from ammonia toxicity with death resulting in less than 30 minutes (Parish and Rhinehart, 2008). Severe toxicity occurred when blood ammonia-N concentrations exceeded 0.7 to 0.8 mg/100 ml (Webb *et al.*, 1972).

Ammonia gas is a highly hydrophilic base and highly irritant to the mucosal tissues when inhaled and it can injure and burn the respiratory tract when combined with water. The base form of ammonia, ammonium hydroxide, dissolves in the water of mucus membranes, hydrolyzes, and rapidly irritates tissues due to the high pH. Ammonia will also increase the blood pH which can change the uptake of oxygen by hemoglobin, that may leads to decreased oxygenation of tissues, and decreased metabolic function (Colorado, 2013). Elevated concentrations of rumen ammonia and subsequent high concentrations of ammonia in peripheral blood are characteristics of the toxicity (Webb et al., 1972).

Common signs of ammonia toxicity include excessive salivation, rapid breathing, tremors, tetany, and eventually death. Bartley *et al.* (1976) suggested to perform a rapid evacuation of rumen contents as a method for treating ammonia toxicity. Drenching with a dilute solution of acetic acid is frequently useful if signs are detected early to neutralize the ammonia and reduce its rate of absorption.

4. Nutrient synchronization

Microbial protein (MCP) synthesis in the rumen is largely depended on the availability of energy (mainly from carbohydrate fermentation) and nitrogen sources (Russell, 2002). Therefore, synchronizing the rates of carbohydrate and protein degradation in the rumen is a strategy to optimize MCP synthesis. When synchronization is achieved, the rate of carbohydrate fermentation is closely matched with that of protein degradation and it will improve the microbial protein synthesis by coupling of energy (ATP) production with ammonia-N release and stimulate the microbial activity. Thus improving MCP supply to the cattle will lead to better animal performance and higher production.

A number of researches (Herrera-Saldana *et al.*, 1990; Robinson and McQueen, 1994; Rotger *et al.*, 2006; Shabi *et al.*, 1998) have been reported on the synchronization of ruminal degradation rate of carbohydrates and CP for improving ruminal microbial protein synthesis and animal performance in dairy cattle. But a few reports have been found on synchronizing the energy sources with protein supplements having similar degradation characteristics.

High concentrate diets are highly degraded and rapidly fermented in the rumen. Consequently, that may lead to accumulation of VFA in the rumen and cause relatively low in ruminal pH (Beauchemin *et al.*, 2001). Low ruminal pH may affect fiber and protein degradation and the efficiency of microbial protein synthesis (Hoover, 1986; Shriver *et al.*, 1986).

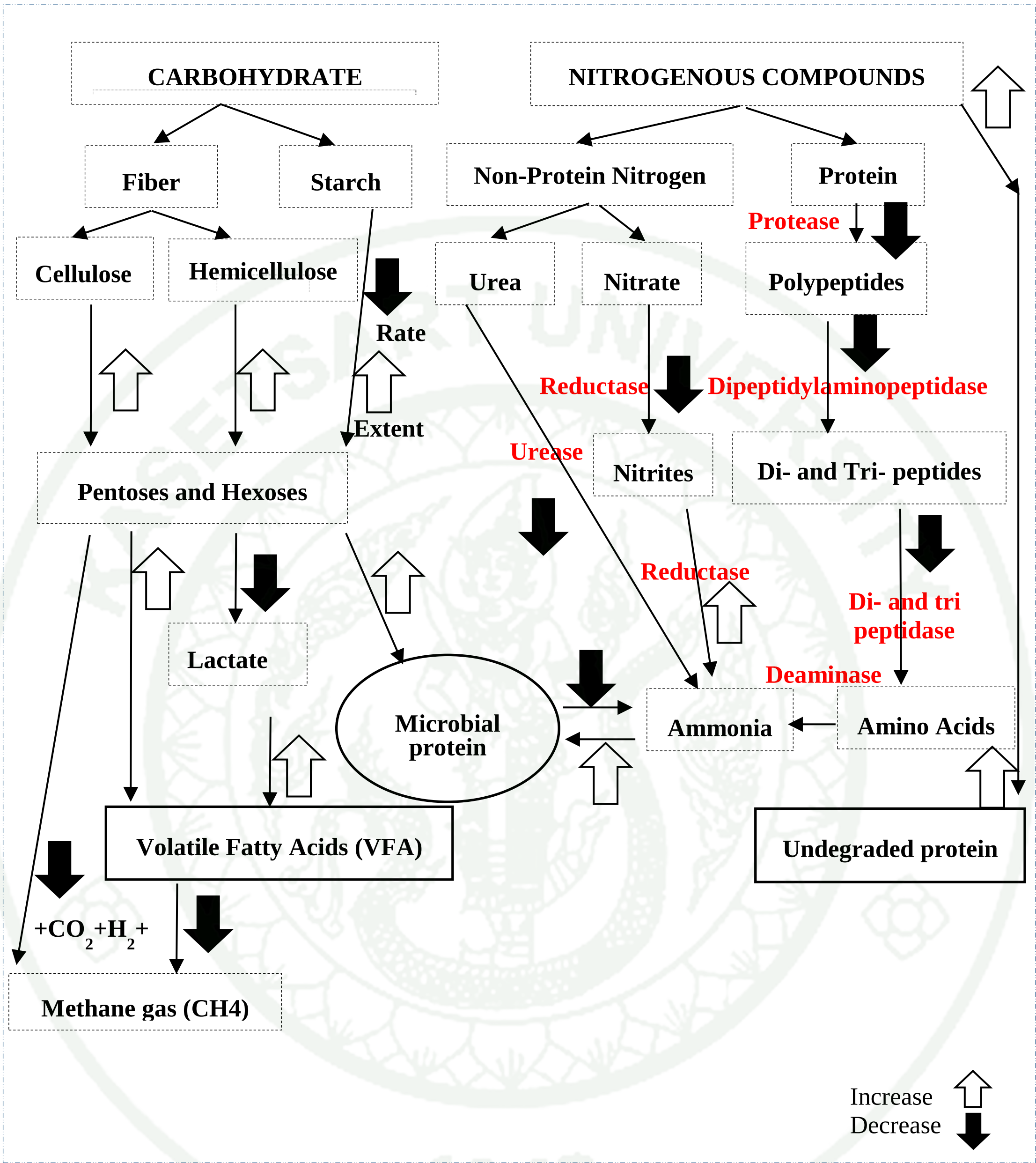
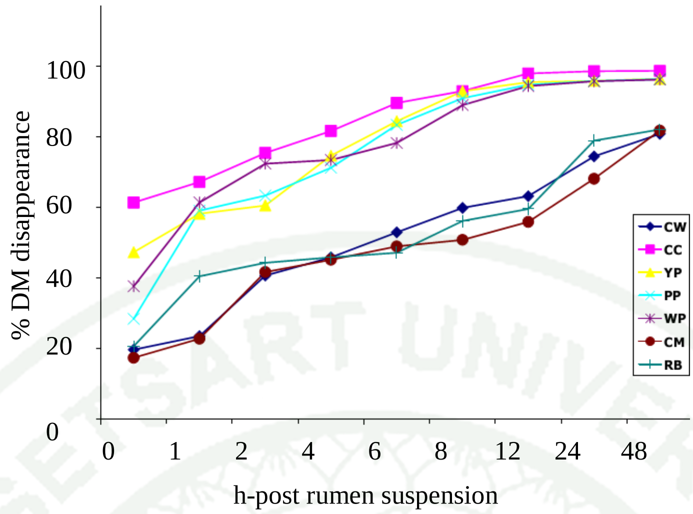


Figure 4 Metabolic path way of carbohydrate and protein in the rumen

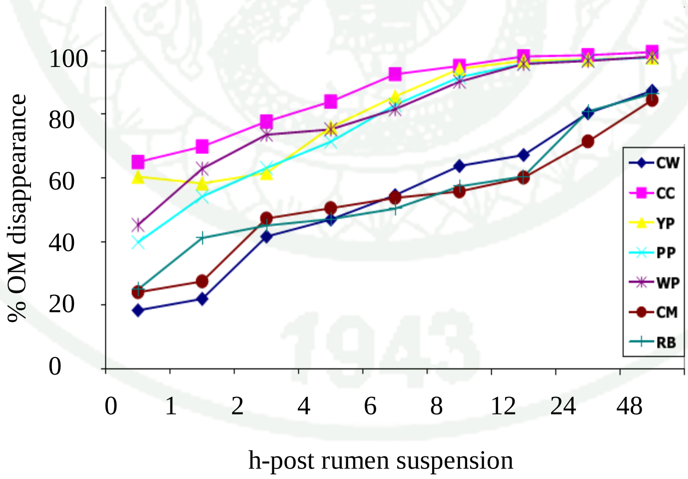
Source: Adapted from (Nagaraja *et al.*, 1997)



CC = cassava chip; YP = yellow sweet potato; WP = white sweet potato; PP = purple sweet potato; RB = rice bran; CW = cassava waste; CM = corn meal) at various h-post rumen suspension

Figure 5 In situ DM disappearances of seven energy sources

Source: Chanjula *et al.* (2003)

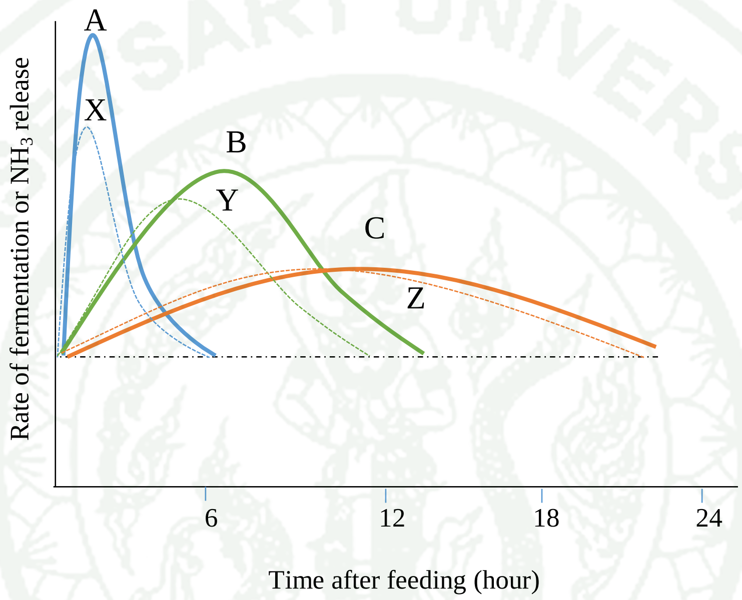


CC = cassava chip; YP = yellow sweet potato; WP = white sweet potato; PP = purple sweet potato; RB = rice bran; CW = cassava waste; CM = corn meal) at various h-post rumen suspension

Figure 6 In situ OM disappearances of seven energy sources

Source: Chanjula *et al.* (2003)

Chanjula *et al.* (2003) stated the amount of DM and OM disappearance characteristics ranked from the highest to the lowest of degradation rate: cassava chip, yellow sweet potato, purple sweet potato, white sweet potato, cassava waste, corn meal and rice bran, respectively and also concluded that cassava chip had the greatest values at all time.



A, B, C = carbohydrate sources and X, Y, Z = rumen nitrogen sources

Figure 7 Illustration of the theoretical rumen fermentation rates over time after ingestion of three forms of feed carbohydrate and rumen-NH3

Source: Adapted from Johnson (1976)

Cassava can be replaced to the use of corn as a high energy source without any adverse effects on the productive performance. However, rumen digestibility of cassava is higher than corn. Theoretically, we should consider to make a balance and synchronous diet which should allow more efficient use of nutrients to enhance production of microbial products, to increase nutrient supply to the animal, and potentially to improve animal production performance (Hall and Huntington, 2008). Therefore, using the cassava chip with ground corn or any other moderately rumen degradable energy sources will be more synchronous to carbohydrate and protein degradation in the rumen when we use urea and soybean meal as a CP source. Soy bean meal and ground corn were moderately degradable in rumen while urea and cassava chip was rapidly degradable in rumen. Therefore, replacement with cassava chip 50% in diet might be better synchronization than replacing cassava chip 100%.

Table 3 Comparison of nutrient contents between corn and cassava

Constituents	Ground corn	Cassava
DM (% AF)	88.00	89.00
NDF (%DM)	9.00	8.00
Lignin (%NDF)	2.22	0.00
TDN (%DM)	88.00	84.00
ME (Mcal/kg)	3.18	3.04
NEm (Mcal/kg)	2.18	2.06
NEg (Mcal/kg)	1.50	1.40
CP (%DM)	9.80	3.10
DIP (%CP)	57.40	56.10
Starch (%NSC)	73.00	80.00
Fat (%DM)	4.30	0.80
Ash (%DM)	1.60	3.00

Sources: NRC (2000)

On the other hand, replacing corn 100% with cassava can give lower feed cost than 50% replacement because the price of cassava chip is less expensive than corn. Furthermore, high digestibility of cassava chip may improve rumen energy supply and enhance the animal performance. Therefore, the second experiment was done to study the effect of TMR feeding with different energy sources (cassava chip and cassava chip plus ground corn) with different crude protein levels (12 and 14%) on the performances, carcass quality and production cost of finishing Kamphaeng Saen beef steers.

Table 4 Price comparison for various energy sources in local market of Thailand

Feed	Price (baht/kg)
Cassava chip	8.80
Ground corn	10.50
Wheat bran	6.00
Molasses	7.00

Sources: These price data are collected from Cowboy Friend feed shop, Kamphaeng Saen, Nakhom Pathom province (October, 2011)

5. Animal performance

Live weight, ADG, and carcass characteristics are important parameters in beef production. But, daily feed intake is important for improvement of animal performance and productive efficiency and diet formulation. Cattle with high feed intake will be higher in feed efficiency than those with a lower feed intake. The amount of feed intake of cattle is related to the energy level of the ration, environment, palatability, feed processing and degree of finish on the cattle (Gillespie and Flanders, 2010).

The animal's physiological state can also markedly alter feed intake. Body composition, especially percentage of body fat, seems to affect feed intake (NRC, 2000). Until the cattle reach about 85 to 90 percent of their market weight, their feed intake tends to increase. Then the feed intake level may decline as they get heavier. Therefore, when heavy cattle begin to decrease feed intake, it shows that they are about ready for slaughter (Gillespie and Flanders, 2010).

6. Carcass composition

Muscle, bone, and fat are the richest tissues found in carcasses and the growth rate of these three tissues is different in the animal maturity stages. In beef cattle production, muscle and fat are the most economically important tissues (Baker and

Mikesell, 2011). The carcass should have a minimum amount of bone, a maximum amount of muscle and an optimum amount of fat which content may change according to consumer choices. Therefore, the correct combination of muscle and fat is important for the beef producer. The carcass should not be composed with too much or too little muscling. Moreover, too much as well as too little fat is also undesirable for consumers. Eventually, the objective of fattening beef cattle is to obtain (more marbling) the right amount of fat in the muscle with less amount of exterior fat cover (Gillespie and Flanders, 2010). Dressing percentage, good carcasses conformation, age of animals and marbling score are important data to determine carcass price.

A number of components such as head, hide, stomach, bowels, heart, lungs, kidney, blood, tail, penis and foot have to be discarded from pre-slaughter live weight to warm carcass weight. Nevertheless, some countries used to eat some parts of carcass and organs (liver, stomach, intestine, kidney, etc.) therefore some modifications could be occurred in a commercially dressed carcass in some countries. There are many factors influencing on the carcass yield or dressing percentage from farm to slaughterhouse. Honikel (2004) stated that Pre-slaughter weight affects dressing percentage, the main increase in dressing percentage seem to occur between 100 and 400 kg live weight with little further change to 600 kg. Fatness also influences on dressing percentage if at equal weight, one animal is fatter than another, it will usually have a higher dressing percentage (Berg and Butterfield, 1976).

Andersen (1975) have shown influences of energy level on the fat content of the gain and final carcass fat content and Andersen *at el.* (1984) stated that increasing live weight at slaughter from 425 to 800 kg improved the dressing percentage as well as the conformation score, The carcasses became fatter, the relative weight of the bone decreased and the lean/bone ratio increased as the carcasses grew heavier. Steen and Kilpatrick (1995) concluded that increasing slaughter weight increased carcass fat content and reduced lean and bone contents, the effects being greater in steers and heifers than in bulls.

7. Meat quality

Meat quality has the compositional quality (lean to fat ratio) and the palatability. Most of the beef carcasses are evaluated by using three parameters: amount of muscle present in the carcass or cutability (more is better), amount of exterior fat cover (less is better) and the quality of the lean meat in terms of color, texture, and marbling (intramuscular fat, more is better) (Gonda *et al*., 1996). Market beef animals are systematically graded in two different ways; quality grade and yield grade (USDA, 1997). Indurain *et al*.(2009) showed that the systemic grading in beef carcass has two objectives: 1) to estimate the yield of saleable meat. 2) to determine the eating quality (palatability) of the meat.

Multiple factors, including palatability, water-holding capacity, color, nutritional value and safety, determine meat quality. The importance of these traits varies depending on both the end product and the consumer profile. Flavor, juiciness and tenderness influence the palatability of meat (Koohmaraie and Geesink, 2006). The quality of meat is highly depended on breed, age, stress, aging, pH, temperature and other causes from growth to slaughter. Transformation of slaughter animals into meat including handling, weighing and loading on the farm, transporting to slaughter house, off-loading and holding at slaughter house and finally slaughtering can lead to unnecessary suffering, injury, stress and poor quality meat production by poor operational techniques and facilities (Grandin, 1994).

7.1. pH and meat quality

After an animal has been slaughtered, blood glucose and oxygen supply to muscle tissue was stopped. Muscle contraction attempted to continue using glycogen. As a consequence, Lactic acid will be accumulated and muscle pH will decline from normal pH 7. When the pH drops to around 5.5, muscles cease to use glycogen. Furthermore, the lactic acid accumulation prohibits movement of sarcomeres and then muscle becomes stiff which is called rigor mortis (Gonda *et al*., 1996).

Stress before slaughter is one of the most important impacts on meat quality of beef cattle. Animals waiting for slaughter can be stressed by many factors such as hunger, thirst, fatigue, injury, rough handling, improper restraint, bad weather, high temperature and unfamiliar pre-slaughter environment. If the animal is stressed by one of those factors during the pre-slaughter period, catecholamines (such as epinephrine and dopamine) will be released and it will stimulate glycogen breakdown and rapidly deplete glycogen (Lacourt and Tarrant, 1985). The depleted levels of glycogen will impact on the ultimate pH (pHu) levels. Stress also has effects on pHu of the raw meat by depleting muscle glycogen reserves (Watanabe *et al*., 1996). The normal ultimate pH in meat (5.5 – 5.6) will not be reached when pre-slaughter muscle glycogen reserves is lower than the critical threshold of 45-55 mmol/kg (Ruiz *et al*., 1995). Meat from such animals exhibits a dark, firm, and dry appearance (DFD). On the other hand, if muscle pH drops too rapidly after slaughter, meat develops a pale, soft and exudative or watery appearance (PSE).

McVeigh *et al.* (1982) concluded that the inherently lower blood glucose concentration and insulin activity in cattle than in non-ruminant species may reduce glucose availability in cattle and thereby delay muscle glycogen recovery. Muscle glycogen deficiency at slaughter usually results in dark-cutting beef. Generally grass-fed cattle have darker meat colour than the ones which grain-fed (Robson, 1995). This is caused by the higher pHu values found in beef from grass-fed compared to grain-fed cattle. Muir (1998) stated that grass-fed steers had higher ultimate pH values than grain-fed steers and suggested that grain-fed steers would be more accustomed to handling and they would be less susceptible to pre-slaughter stress than grass-fed steers. In addition, pre-slaughter glycogen depletion would be less in grain-fed steers. However, French *et al.* (2000) and Razminowicz *et al*. (2006) found no such difference in ultimate pH between grass-fed and grain-fed steers.

7.2. Colour and meat quality

Meat colour is the most important factor affecting consumer acceptance, purchasing decisions and satisfaction of meat products. Meat colour may be influenced by many factors such as breed and age of the animal, muscle type, enzymes, diet, even the activity done by the animal.

There are two main types of myofibers, distinguished by color and relative speed of contraction. The first type, fast white fibers are large in diameter, have few blood vessels running through them and use primarily stored glycogen as energy source. Large muscle groups mostly consist of the fast, white fibers. Anaerobic exercise tends to develop this type of muscle fiber. Conversely, the second type slow red fibers use mainly glucose from the blood stream, have many blood vessels running through them and are red in appearance. Aerobic exercise can develops this type of muscle fiber (Gonda *et al*., 1996)

The type of myofiber that predominates in an animal is largely controlled by genetics and varies by muscle group. If an animal is subjected to stresses that favor a specific fiber type, fibers have the ability to slowly transform through the intermediate types toward the favored type (Gonda *et al.*, 1996). Grass-fed animals have darker meat than the ones which grain-fed (Robson, 1995). This is caused by the higher pHu values found in beef from grass-fed compared to grain-fed cattle. Robson (1995) hypothesised that grass-fed steers are more susceptible to pre-slaughter stress and associated pre-slaughter glycogen depletion than grain-fed steers as the latter would be better accustomed to penning and handling.

Colour measurements are usually done using the L*, a*, b*system. The measurement system has three fundamental colour coordinates; L* (lightness), a* (positive red, negative green) and b* (positive yellow, negative blue) (CIE, 1978). Myoglobin is responsible for the majority of the red meat colour. Normally, Its colour is purplish but it becomes a bright red colour when it is mixed with oxygen. The remaining red comes from the circulating blood haemoglobin. However, it can be found a few amount in the tissues after slaughtering process (Priolo *et al*., 2001).

When the muscle glycogen has been used up rapidly during the handling, transport and pre-slaughter period, the results after slaughter is little lactic acid production which result in DFD meat, and this condition is measured by an L* coordinates. The quality of DFD meat is low because it is not much tasty and the dark colour is unpleasant to the customer and it has a shorter shelf life due to the high pH value which favour to bacterial growth (Priolo *et al*., 2001). Zhang *et al.* (2005) found that high pH meat had lower L* (lightness), a* (redness), b* (yellowness), hue angle (degrees) and chroma (saturation) values than normal pH meat, indicating that high pH meat was darker and less brown than normal pH meat.

Animals fed on pasture have a yellow fat colour because of the high levels of beta-carotene contained by grass. This yellow fat colour is measured objectively by b* coordinate. Consumers often see beef with yellowish fat as it come from an old or infected animal.

Vestergaard *et al.* (2000a) reported less glycogen, a higher pH, and darker lean from younger bulls that were fed a forage-limited diet than those fed a concentrate *ad libitum*. These authors speculated that the decreased dietary energy on the forage-limited diet favoured an increase in oxidative muscle metabolism. An increase in oxidative muscle metabolism could possibly allow for the decreased necessity to store comparable amounts of muscle glycogen as muscle with a higher glycolytic capacity. The resultant pH differences caused differences in yellowness (b*). Vestergaard *et al*. (2000b) reported a negative correlation between pH and b*values.

7.3. Water holding capacity (drip loss and grilling loss)

Water holding capacity (WHC) is the ability of meat ability to retain inherent water during application of external forces such as cutting, heating, grinding, or pressing and it is one of the most important quality characteristics of meat products and a factor that also determines the juiciness of meat. It is important to meat processing in that as proteins are able to hold more water they become more soluble (Zhang *et al*., 2005).

Lean muscle contains approximately 75% water. Some of them exist in muscle cells and found very closely bound to protein (bound water). It is very tolerant to cold and to being motivated off by regular heating. Much of the water in muscle is entrapped either intramyofibrillar spaces or extramyofibrillar spaces. During rigor mortis, the space for water in the myofibrils is gradually reduced and fluid can be forced into the extramyofibrillar spaces where it is more easily lost as drip. Limited degradation of cytoskeletal proteins may result in increased shrinking of the overall muscular tissue, which is eventually interpreted into drip loss (Huff-Lonergan and Lonergan, 2005).

Once the beef is cut, the amount of water and location of that water in meat can change based on numerous factors related to the tissue itself and how the product is handled (Honikel, 2004). In meat WHC is at a minimum at the iso-electric point (pI) of proteins. At this point, equal positive and negative charges on the amino acids side chains result in a maximum number of salt bridges between peptide chains and a net charge of zero. The pI of meat is in the pH range of 5.0 to 5.5 which is also the pH of meat after it has gone through rigor mortis. The exposure of proteins to a low pH at high temperatures causes less water to be retained between actin and myosin filaments, thus increasing exudates (drip loss). Actin and myosin are important in the formation of a protein lattice necessary for binding water and fat in further processed meat products (Zhang *et al.*, 2005). Increasing or decreasing the pH away from the pI will result in increased water-holding capacity by creating a charge imbalance. A charge imbalance is a predominance of either positive or negative charges which will lead to a repulsion of charged protein groups of the same charge. This repulsion results in increased capacity for water retention and lead to a juicy meat. Zhang *et al.* (2005) reported higher water holding capacity in high pH meat than in normal pH meat.

7.4. Meat tenderness

Tenderness can be attributed to a person's perception of meat, such as: softness to tongue, resistance to tooth pressure and adhesion. Tenderness of beef is influenced by animal’s age, sex, live weight, breed and ante mortem stress.

Tenderness varies mainly due to changes to the myofibrillar protein structure of muscle in the period between animal slaughter and meat consumption. To maximize the benefits of post-mortem storage on meat tenderness, beef should be stored for 10-14 days, lamb for 7-10 days, and pork for 5 days (Koohmaraie, 1996). if the carcass is refrigerated too hastily immediately after slaughter, muscle fibres contract severely, and the result is ‘cold shortening’ which will need a force to shear the fibres after cooking (Razminowicz *et al.*, 2006). Thus, the tougher the meat, the more force required to shear it and that is known as the Warner-Bratzler shear force (WBSF) test. A relationship has been established between the tenderness of cooked meat and its pHu. As the pH, raises from 5.5 to 6.0, the tenderness decreases; this effect then reverses as the pH, increases above 6.0. Silva *et al*.(Silva *et al.*, 1999) concluded that in beef, tenderness at 1, 6 and 13 days increased linearly with increasing ultimate pH (5.5 to 6.7).

Meat tenderness is a function of the collagen content, heat stability and the myofibrillar structure of muscle (Muchenje *et al.*, 2009). These, however, appear to be affected mainly by the rate of growth of the animal rather than breed. The myofibrillar component of tenderness can also be influenced by the calpain proteolytic enzyme system during ageing of the carcass post-mortem. Wheeler and Koohmaraie (1991) suggested that the myofibrillar component could be a more important factor than the connective tissue characteristics in influencing meat tenderness. Pasture beef turned out to have WBSF than conventional beef (Razminowicz *et al.*, 2006). However, French *et al*. (2000) found no difference in WBSF between beef produced on grass-based and concentrate-based diets.

Koohmaraie *et al.* (2002) suggested sarcomere length, connective tissue and proteolysis of myofibrillar proteins could explain most of the variation observed in aged meat, with proteolysis being the main biochemical factor contributing to the variation in tenderness. Maher *et al.* (2005) found that variation in proteolysis was greater than the other biochemical, chemical and tenderness quality attributes in Belgian Blue steers managed homogenously pre and post-slaughter. Furthermore, Koohmaraie *et al.* (2002) hypothesised that protein degradation occurs at different rates in different animals, which may contribute to the variation in tenderness of beef. Stolowski *et al.* (2006) found that aging can improve WBSF values up to 14 days; and, postmortem aging beyond 14 d may not be effective in improving WBSF of steaks from cattle with a large *Bos indicus* influence.

Regarding to the uses of different energy sources and protein levels, several authors reported no differences in WBSF values and sensory evaluation on beef eating qualities due to using different energy sources including cassava. Yimmongkol *et al*. (2009) showed no differences on sensory evaluation of eating qualities by replacing cassava meal with 50% and 100% dry cassava pulps and Laorodphan *et al.* (2012) also resulted no effects on WBSF by replacing corn and rice bran with 50%, 75% and 100% dry cassava pulps

8. Summary of literature review

There are several factors interacting with or affecting on the performance, carcass quality of beef cattle. The factors range from the different nutrients input that are supplied to animal, the ways the animals are treated prior to slaughter, post-slaughter handling and the method of keeping meat in store, shops and home. However, the objectives of the current research were to study the performance, carcass quality and production cost of the Kamphaeng Saen beef cattle by using different energy sources and different crude protein levels in the growing period and finishing period.

MATERIALS AND METHODS

Experiments

Experiment 1: Effect of supplementary concentrate feeding levels (1.0 and 1.5 % of body weight) with different crude protein levels (14 and 16%) on the performances of Kamphaeng Saen young bulls fed on para grass (*Brachiaria mutica*)

Experiment 2: Effect of TMR feeding with different energy sources (cassava chip and cassava chip plus ground corn) and different crude protein levels (12 and 14%) on the performances, carcass quality and production cost of finishing Kamphaeng Saen beef steers

Experimental Location

The two experiments were conducted at Buffalo and Beef Cattle Production Research and Development Center, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom province, Thailand.

Experiment 1: Effect of supplementary concentrate feeding levels (1 and 1.5 % of body weight) with different crude protein levels (14 and 16%) on the performances of Kamphaeng Saen young bulls fed on para grass **(***Brachiaria mutica*)

1. Experimental Design and Treatments

In this experiment, 2×2 Factorial in Completely Randomized Design with an initial BW covariate was used. Sixteen young bulls were selected from the herd of the BRDC center and treatments were assigned randomly in the herd.

The 4 treatment combinations were:

T1 = concentrate feeding level 1.0 % of BW and 14 % CP level
T2 = concentrate feeding level 1.5 % of BW and 14 % CP level
T3 = concentrate feeding level 1.0 % of BW and 16 % CP level
T4 = concentrate feeding level 1.5 % of BW and 16 % CP level

The statistical model is:

$$Y_{ijk} = \mu + X_{ij} + A_i + B_j + AB_{ij} + \varepsilon_{ijk}$$

Where:

Y_{ijk} = observation k in group i and j (treatment i and j)
μ = the overall mean
x_{ij} = a continuous BW independent variable with mean µx (covariate)
A_i = the fixed effect of concentrate feeding level, i = 1, 2
B_j = the fixed effect of CP level, j = 1, 2
AB_{ij} = the interaction between treatment i and j
ε_{ijk} = random error

2. Experimental Feed Preparation

The feed compositions of the two concentrates used in the first experiment are shown in Table 5. All treatments were prepared at BRDC center and the representative feed samples were collected from each batch and evaluated the nutrient composition.

Table 5 Experimental feed compositions (concentrate)

Ingredient Composition (%)	14 % CP	16 % CP
Cassava chip	36.89	34.39
Soybean meal	8.00	10.00
Palm expeller (solvent extracted)	30.00	30.00
Palm expeller (pressed)	15.00	15.00
Molasses	8.00	8.00
Urea	1.00	1.50
Sulfur	0.01	0.01
Salt	0.50	0.50
Di-Calcium phosphate	0.10	0.10
Premix[1/]	0.50	0.50
Total	100.00	100.00

[1/] Agromix beef No. 46: vit A = 2,160,000 IU, vit B3 = 100,000 IU, vit E = 5,000 IU, Mn = 8.5 g, Zn = 6.4 g, Cu = 1.6 g, Mg = 16 g, Co = 320 mg, I = 800 mg, Se = 32 mg

Table 6 Approximate nutrient composition of experimental feeds

Approximate nutrient composition	14 % CP	16 % CP
TDN[1/] (%)	72.38	71.88
NE (Mcal/kg)	1.60	1.59
CP (%)	13.95	15.94
RUIP (%)	3.29	3.47
Ca (%)	0.39	0.39
P (%)	0.19	0.19
NDF (%)	37.60	37.63

[1/] by caculation

3. Experimental animals arrangement and management

Sixteen medium-frame young bulls, average BW (200kg) of Kamphaeng Saen breed [50% Charolaise × (25% American Brahman x 25% Thai native cattle)] were selected for the experiments. The experimental young bulls were chosen from the herd of the BRDC center by their age and BW. The young bulls were individually identified by numbered ear tattoo and then kept in individual pens. All of them were treated against intestinal parasites using Albendazole (2 ml per 100 kg BW) and Ivermectin (1 ml per 4 kg BW) and vaccinated against Foot and Mouth Disease.

All young bulls were weighed and kept in individual pens. They were fed para grass (*Brachiaria mutica*) *ad libitum*. Treatments were randomly assigned and offered twice per day, in the morning (08:00 am) and evening (05:00 pm). During the experimental period, each animal was arranged for free access to clean drinking water and a mineral lick block containing Na = 136 g/kg, Ca = 140 g/kg, P = 60 g/kg, Mg = 20 g/kg, K = 25 g/kg, S = 12 g/kg, Fe = 1000 mg/kg, Zn = 800 mg/kg, Mn = 350 mg/kg, Cu = 300 mg/kg, Co = 80 mg/kg, I = 245 mg/kg, Se = 20 mg/kg.

4. Data collection

They were weighed again to record initial body weight at the end of the adaptation period (approximately 14 days) when the young bulls settled down to the pen and feed intake was stable. Feed intake (FI) was recorded daily by weighing grass before feeding and left over grass after removing from each feed trough in the next morning. DMI, ADG and FCR were measured as animal performance data. Initial and final BW of each bull was recorded at the start and end of the experiment. The mean of the BW was used as the initial and final weight and monthly body weight were also recorded throughout the trial at the same intervals to determine the performance results. After the feeding trial, the young bulls were fleshed out with pre-finishing ration for the next experiment.

5. Data calculation

DMI, ADG and FCR were calculated by the performance data of each animal. Feed intake was analyzed as total dry matter intake, concentrate intake, grass intake and each nutrient intake.

$$\text{Daily Feed Intake} = \frac{\text{feed given -left over feed}}{\text{duration of feeding trial}}$$

ADG was calculated by subtracting initial BW from final BW and the BW difference was divided by the duration of feeding trial (126 days).

$$\text{Average Daily Gain} = \frac{\text{final BW – initial BW}}{\text{duration of feeding trial}}$$

FCR was calculated by dividing total DMI by total BW gain.

$$\text{Feed Conversion Ratio} = \frac{\text{total DMI}}{\text{total BW gain}}$$

6. Statistical analysis

The effects of different concentrate feeding levels and CP levels on growing performance and feed cost were analyzed statistically by ANOVA using the general linear model procedure. The treatment means were used to compare the different results by using Duncan's New Multiple Range Test (DMRT).

Experiment 2: Effect of TMR feeding with different energy sources (cassava chip and cassava chip plus ground corn) and different crude protein levels (12 and 14% CP) on the performances, carcass quality and production cost of finishing Kamphaeng Saen beef steers

The second experiment was started group by group in which steers would have 350 kg of body weight on average. The feeding trial lasted for 120 days until the animals reached the local market weight (500-550 kg).

1. Experimental Design and Treatments

In the second experiment, 2×2 Factorial in Randomized Complete Block Design was used. The blocks were arranged by the periods in which four animals with the same BW (350 kg) have reached were used.

The model for the experimental design (Kaps and Lamberson, 2004) is:

$$Y_{ijk} = \mu + Bl_i + A_j + B_k + AB_{jk} + \varepsilon_{ijk}$$

Where:

Y_{ijk} = an observation in treatment j,k and block i
μ = the overall mean
Bl_i = the fixed effect of block, i = 1,2,3,4,5,6
A_j = the effect of energy sources, j = 1,2
B_k = the effect of protein levels, k = 1,2
AB_{jk} = the interaction between treatment j and k
ε_{ijk} = random error with mean 0 and variance σ^2

The four finishing treatment combinations are:

T_1 = cassava chip (36%) and 12% CP based TMR (cTMR12)

T_2 = cassava chip + ground corn (18:18%) and 12% CP based TMR (ccTMR12)

T_3 = cassava chip (36%) and 14% CP based TMR (cTMR14)

T_4 = cassava chip + ground corn (18:18%) and 14% CP based TMR (ccTMR14)

2. Experimental Feed Preparation

Table 7 Experimental feed ingredients and composition

Ingredient Composition %	Treatments			
	cTMR12	ccTMR12	cTMR14	ccTMR14
Cassava chip	36.00	18.00	36.00	18.00
Ground corn	-	18.00	-	18.00
Soybean mean	5.00	1.50	10.00	7.00
Palm expeller (solvent extracted)	17.05	20.55	11.85	14.85
Palm expeller (pressed)	20.00	20.00	20.00	20.00
Luecaena	10.00	10.00	10.00	10.00
Molasses	10.00	10.00	10.00	10.00
Urea	0.80	0.80	1.00	1.00
Sulfur	0.05	0.05	0.05	0.05
NaCl	0.50	0.50	0.50	0.50
Di-Calcium phosphate	0.10	0.10	0.10	0.10
Premix[1/]	0.50	0.50	0.50	0.50
Net	100.00	100.00	100.00	100.00

[1/] Agromix beef No. 46: vit A = 2160000 IU, vit B3 = 100000 IU, vit E = 5000 IU, Mn = 8.5 g, Zn = 6.4 g, Cu = 1.6 g, Mg = 16 g, Co = 320 mg, I = 800 mg, Se = 32 mg

The feed compositions for each TMR were as in Table 7. All treatments were ordered from the feed factory nearby and the representative feed samples were collected at least five times from each batch and all these samples from the same batch were sampled again to make single sample and the sample were analyzed to evaluate the nutrient composition of the TMR.

Table 8 Approximate nutrient composition of experimental feeds

Nutrients composition[1/]	Treatments			
	cTMR12	ccTMR12	cTMR14	ccTMR14
TDN (%)	72.03	70.17	73.15	71.40
NE (Mcal/kg)	1.58	1.58	1.60	1.61
CP (%)	12.09	12.16	14.00	14.20
RUIP (%)	2.88	2.96	3.28	3.41
Ca (%)	0.44	0.39	0.43	0.38
P (%)	0.17	0.17	0.17	0.17
NDF (%)	35.76	39.57	32.91	36.43

[1/] by calculation

3. Experimental animal arrangement and management

The second experiment was performed immediately after the first experiment. The young bulls were grouped into six blocks of four animals each according to the BW on reaching 350 kg. Therefore, the first four bulls with a BW of around 350 kg were constituted as block 1. Then, they were castrated and administered preventive treatment of Albendazole (2 ml per 100 kg BW) and Ivermectin (1 ml per 4 kg BW), and the four treatments were then assigned at random to the four animals in the block. The steers were weighed again at the end of the adaptation period (approximately 14 days) when their feed intake was stable. Other bulls less than 350 kg BW were fed pre-finishing ration (high protein level TMR) to increase their weight until the next block could be grouped in the similar way.

The animals were kept in individual pens with roof and concrete floor and fed *ad libitum*. The feeds were offered twice per day, in the morning (08:00 am) and evening (05:00pm). During the experimental period, each animal was arranged for free access to clean fresh drinking water.

4. Performance data collection

DMI, ADG and FCR were measured for animal performance data. DMI were measured by weighing TMR before feeding and residual feed after removing from each feed trough. Daily feed consumption was recorded and refusals were collected from individual animals in the morning of the next day.

Steers were weighed at the start and end of the experiment. The mean was used as the initial and final weight and monthly body weight was also recorded throughout the trial at the same intervals to determine ADG and FCR.

5. Carcass quality data collection

Steers were transported to slaughter house (Animal Produce Research and Development Center, Kasetsart University, Kamphaeng Saen Campus) at the end point of the experiment (after 120 days on feed). The steers were weighed immediately prior to slaughter to record final weight (slaughter weight). All steers were deprived of feed, but with free access to water. After the fasting period, the steers were stunned and humanely slaughtered.

5.1. Warm carcass weight and chilled carcass weight

Immediately after the slaughtering process the weight of the head, hide, intestinal tract, and internal organs were recorded on the slaughter dressing floor. Warm carcass weight was taken shortly after slaughter. Dressing percentage is the percentage of weight change transforming the live animal as carcass. It was calculated from the following formula (Cole *et al*., 1968; S. Yimmongkol *et al.*, 2009):

$$\text{Dressing \%} = \frac{\text{Warm carcass Weight}}{\text{Live weight}} \times 100$$

Carcasses were chilled at 0–2°C for 7 days, after 7 days chilling, chilled carcass weights of each carcass were recorded and chilling losses was calculated by the following formula (Orellana *et al.*, 2009):

$$\text{Chilling loss \%} = \frac{\text{(Warm carcass Weight – Chilled Carcass Weight)}}{\text{Warm carcass Weight}} \times 100$$

5.2. Drip loss

Meat sample from *Longissimus dorsi* muscle (LD) at the surface between 12th and 13th rib was trimmed, squared and weighed. Each sample was wrapped with dry clean bandage to absorb water drained from the meat and hung with a hook so that the water from meat could drain out. All samples were hung on a stand in a room at 4°C for 24 hr. drip loss percent was calculated by the following formula (Orellana *et al.*, 2009):

$$\text{Drip loss \%} = \frac{\text{(initial weight – final weight)}}{\text{initial weight}} \times 100$$

Meat samples of LD muscle at the surface between 12th and 13th ribs from the right side of each carcass were collected and then kept frozen for waiting further analysis of the meat quality, color and tenderness.

5.3. Carcass temperature and pH level

Carcass temperature and pH level were measured at 1 hour and 24 hour post-mortem from the muscle of the lumbar region (between 4th and 5th lumbar vertebrae) by using a portable meter with penetrating electrode probe (TESTO205 pH/Temperature meter). Two measurements were made for each carcass (Orellana *et al.*, 2009).

5.4. Back fat thickness and Rib eye area

Back fat thickness was measured using a caliper over the LD muscle of 12th ribs at three-fourths the length of the rib eye muscle from the chine (backbone) (Orellana *et al.*, 2009; Yimmongkol *et al.*, 2009).The area of the rib eye was measured by using semi transparence paper and reading with a device called planimeter. This device was used to measure outline of the eye muscle (Yimmongkol *et al.*, 2009).

5.5. Abdominal fat and entrails weigh

Kidney, pelvic and heart fat (% KPH) is usually expressed in percentage and it is represented as a percentage of total fat found in the body cavity of a carcass specifically in the regions of the kidneys, pelvis and heart. It was calculated based on the change in carcass weight following removal of fat from these areas on the carcass. Entrails weigh was measured at the same time.

5.6. Marbling score

Marbling was evaluated by estimating of the amount of intramuscular fat present visible on the cut surface of the rib eye muscle between 12th and 13th rib (NBACFS, 2005). Usually this is done after the carcass has cooled and begun the aging process. At this time the marbling is easier to see (Score from 1 to 5; 1= no marbling and 5 = highest marbling).

5.7. Meat colour

Meat colour was assessed by the L*, a*, b*system (CIE, 1978) using a colour meter (Mini Scan EZ, 4500L, USA) to determine the colorimetric index of chromaticity. Color was measured on the fat-free surface of the *Longissimus dosi* muscle between 12th and 13th ribs after cutting a slice and blooming. Four colour determinations were taken and the mean value was used for evaluation.

5.8. Grilling loss and tenderness

Grilling loss and tenderness were estimated in the meat samples from the *longissimus dorsi* muscle between 12th and13th ribs. Samples were thawed at room temperature and trimmed and squared in order to provide an approximately 200 g rectangular samples. Each sample was weighed and grilled in oven at 120°C for 15 min. After cooling down to room temperature, grilled meat was weighed again and grilling loss was expressed as the percentage loss related to the initial weight.

Then core samples were used to determine tenderness by shear force and the samples were cut into 1 cm^2 cross-sections and 2–3 cm in length with the fibers perpendicular to the direction of the blade with their lengths paralleled to the fiber axis. Shear force test was performed using Warner Bratzler Shear device (Challion; G-H ELEC. MFG Co. Ltd., U.S.A.). Cores were sheared across the fiber axis by a V-shaped cutting blade with a shearing velocity of 200 mm min^{-1}. The shear force value from each steak was recorded and the average value was used for evaluation (Yimmongkol *et al*., 2009).

6. Chemical analysis

During the trial, the feed offered and individual feed refusals were sampled and pooled to one sample from two months sample collection. 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). DM (ID 930.15), CP (ID 976.05), and ash (ID942.05) were analyzed according to the standard methods of AOAC (1990). NDF and ADF concentrations were determined according to the procedure of Van Soest *et al.* (1991).

7. Production cost calculation

Production cost and profit of each cattle were calculated as follow:

7.1. Cattle cost

Cattle cost = initial live weight × price

7.2. Feed cost

Feed cost = feed intake × price

7.3. Management cost

Management cost included capital investment expenditures (depreciation price of land, building, utensils, etc.) and current expenses (wages, medicine, water, electricity, fuel, materials, interests, others, etc.).

7.4. Total cost

Total cost = Cattle cost + Feed cost + Management cost

7.5. Income

Carcass price was determined by local market pricing method (KU beef) as follow:

1. Age (estimating by tooth replacement)
2. Marbling score
3. Carcass percentage

Carcass price = chilled carcass weight × price

7.6. Profit/loss

Profit/loss = Total income -Total cost

$$\text{Profit \%} = \frac{\text{profit}}{\text{total cost}} \times 100$$

8. Statistical analysis

All data, the effect of TMR feeding with different energy sources and different crude protein levels on the performances, carcass quality and production cost were analyzed statistically by ANOVA using the general linear model procedure. The treatment means were used to compare the different results by using Duncan's New Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Experiment 1: Effect of supplementary concentrate feeding levels (1.0 and 1.5 % of body weight) with different crude protein levels (14 and 16%) on the performances of Kamphaeng Saen young bulls fed on para grass (*Brachiaria mutica*)

1. Chemical analysis of concentrate feeds and grass

Chemical analysis of nutrient composition in experimental concentrate feeds and para grass (*Brachiaria mutica*) are shown in Table 9. During the winter and early summer, the grass used in this experiment reflected harvesting time resulting in the relatively high fiber (NDF of 729.9 g/kg DM) and low CP (55.6 g/kg DM) contents.

Table 9 Nutrient composition of concentrate and para grass (*Brachiaria mutica*)

Nutrient composition	Concentrate		Para grass
	14 % CP	16 % CP	
Moisture	9.69	10.79	61.53
Crude protein (%DM)	14.62	16.07	5.56
Ether extract (%DM)	2.85	2.90	1.52
Crude fiber (%DM)	16.96	11.75	35.86
Neutral detergent fiber (%DM)	38.83	35.10	72.99
Acid detergent fiber (%DM)	23.40	24.17	44.23
Ash (%DM)	8.75	7.35	8.53
Calcium(%DM)	0.61	0.61	0.65
Phosphorus (%DM)	0.34	0.35	0.19
Gross energy (cal/kg)	4,641.04	4,706.32	4,211.57
Cost[1/] (baht/kg)	7.94	8.03	0.35

[1/] by calculation

2. Growing performance

Table 10 Effects of supplementary concentrate feeding levels on the performance of Kamphaeng Saen young bulls

Performance	Concentrate feeding levels		SEM[1/]	*P* - value
	1.0 % BW	1.5 % BW		
No. of bulls	8	8	-	-
Initial BW (kg)	211.00	214.36	-	-
Final BW (kg)	304.63	349.25	11.17	0.0003
ADG (kg)	0.74	1.07	0.05	0.0003
FCR	11.28	8.88	0.42	0.0058
Dry matter intake (conc.+grass)				
Total DMI (kg)	1,039.83	1,188.82	26.02	0.0002
kg/d	8.25	9.44	0.21	0.0002
% BW/d	3.24	3.37	0.07	0.0004
$g/BW^{0.75}$	129.11	137.65	1.94	0.0001
Dry matter intake (conc.)				
Total conc. intake (kg)	296.04	478.88	26.69	<0.0001
kg/d	2.35	3.80	0.21	0.0002
% BW/d	0.91	1.35	0.06	<0.0001
Dry matter intake (grass)				
Total grass (kg)	743.79	709.93	9.54	0.0379
kg/d	5.90	5.63	0.08	0.0379
% BW/d	2.33	2.02	0.08	0.0249

[1/] standard error of the mean

There was no significant interaction between two factors (supplementary concentrate feeding levels and crude protein levels) on the performance and nutrient intakes during feeding trial. Final live weight, ADG and FCR were significantly higher ($p < 0.01$) with 1.5% of BW concentrate feeding level as shown in Table 10. Cattle consuming poor-quality forage generally respond positively to supplemental concentrate feeding. Supplementary feed including NFC with urea improves palatability of the supplement and animal performance (Sommart *et al.,* 2000). In agreement with the results obtained by Marino *et al.* (2006) in Podolian young bulls, increasing the concentrate proportion produced an increase in growth rate.

Total feed intake and concentrate intake whether expressed in kilograms (kg/d) or on a percent of BW basis, was highly significance ($p < 0.001$) with 1.5% of BW concentrate level. Conversely grass intake ($p < 0.05$) decrease with higher level concentrate feeding. Cattle liked to eat concentrate than grass because of palatability. Therefore, when we fed concentrate, they would eat it all and then they tried to eat grass until their satisfaction was completed. As the grass used in this experiment was relatively high fiber (NDF of 729.9 g/kg DM) and low CP (55.6 g/kg DM) contents, their grass intake would stop when they felt full. Ruiz *et al.* (1995) demonstrated that increased dietary NDF concentration linearly decreased DMI because of physical fill.

Reduced rate of fiber digestion in the rumen is often due to low rumen pH and/or an insufficiency of essential substrates for rumen microorganisms. Feeding high-energy feedstuffs will result negative associative effect on utilization of roughages and rumen fermentation (Zinn and DePeters, 1991). Cellulolytic species can only survive in a weak acid condition. Digestion of high-energy feedstuffs will improve the growth of amylolytic bacteria which produce relatively strong acid (propionate) and lactic acid producing bacteria which produce strong acid (lactate). As a consequence, rumen pH will be dropped and pH lower than 6.0, inhibits cellulolytic species and decreases utilization of forages.

No significant difference was observed on ADG (0.91 and 0.90 kg/d), FCR (9.93 and 10.23 kg) and total DMI (1,112.11 and 1,116.54 kg) by feeding different crude protein levels concentrate (Table 11). However, final BW was statistically significant ($p < 0.05$) between two groups fed with 14 % CP and 16 % CP concentrate (331.00 and 322.88 kg). That would be effect of grass quality and readily degradable NPN source using during feeding trial. Non protein nitrogen (supplied as urea 1.0% for 14%CP and 1.5% for 16% CP) was used in the experimental concentrate feeds.

The rapid hydrolysis of urea to ammonia and the slow digestion of low quality grass in the rumen could not match the energy and N supply for microbial protein synthesis.

Table 11 Effects of crude protein levels on the performance of Kamphaeng Saen young bulls

Performance	Crude protein levels		SEM[1/]	*P* - value
	14 % CP	16 % CP		
No. of bulls	8	8	-	-
Initial BW (kg)	215.75	209.63	-	-
Final BW (kg)	331.00	322.88	11.17	0.0499
ADG (kg)	0.91	0.90	0.05	0.7590
FCR	9.93	10.23	0.42	0.6381
Dry matter intake (conc.+grass)				
Total DMI (kg)	1,112.11	1,116.54	26.02	0.8215
kg/d	9.82	9.85	0.21	0.4727
% BW/d	3.25	3.36	0.07	0.0640
$g/BW^{0.75}$	131.66	135.10	1.94	0.1097
Dry matter intake (conc.)				
Total conc. intake (kg)	392.70	382.23	26.69	0.1922
kg/d	3.12	3.03	0.21	0.1922
% BW/d	1.13	1.13	0.06	0.9610
Dry matter intake (grass)				
Total grass intake (kg)	719.41	734.31	9.54	0.4048
kg/d	5.71	5.83	0.08	0.4048
% BW/d	2.12	2.23	0.08	0.0634

[1/] standard error of the mean

Forage intake and digestibility limitations was consequently observed providing a high concentration of degradable intake protein with low-quality forages (Baker and Mikesell, 2011; Heldt *et al.*, 1999b). However, Razminowicz *et al.* (2006) and Sanson *et al.* (1990) stated that supplemental DIP enhanced the use of low-quality forage and feeding proper amount of supplements containing both DIP and starch or sugars to cattle consuming low-quality forage will improve total digestible organic matter intake.

Depression in forage utilization and animal performance would occur when high level substitution of NPN for true protein and lower levels of urea inclusion have less of an impact on forage utilization and cattle performance (Helmer and Bartley, 1971; Khy *et al.*, 2000). More reasonable recommendations would be for not more than 1% in the concentrate, approximately 135 g/cow daily, and not more than 20% of total dietary CP coming from added urea-NPN sources (Olson *et al.*, 1999).

In the result of Caplis *et al.* (2005) Silage intake decreased, and total DM intake increased, with increasing concentrate level. Supplementing starch was generally negative effects on low-quality forage intake and fiber digestion especially when insufficient RDP relative to starch was used (Baker and Mikesell, 2011). Many studies reported feeds containing high amounts of starch has depressed forage intake (Razminowicz *et al.*, 2006; Zagrobelny *et al.*, 2004). Supplementary feeding of non-fiber carbohydrate if sufficient supplemental RDP is provided, negative effects on fiber digestion can be avoided (Arroquy *et al.*, 2004a).

3. Nutrient intake

Table 12 presents a summary of nutrients intake by feeding supplementary concentrate different feeding levels in the growing period. Gross energy intake, CP intake, ether extract intake, calcium intake and phosphorus intake were significantly higher in 1.5%BW supplementary concentrate feeding group at overall feeding period. However, crude fiber intake, neutral detergent fiber intake and acid detergent fiber intake were not statistically different by feeding different supplementary concentrate feeding levels.

Table 13 presents a summary of nutrients intake by feeding different dietary CP levels in the growing period. CP intake significantly increased in 16% CP concentrate feeding group than 14% CP group during the experiment. Nevertheless, other nutrients (GE, EE, Ca, P, CF, NDF and ADF) were not statistically different by feeding supplementary concentrate with different crude protein levels.

Table 12 Effects of supplementary concentrate feeding levels on nutrient intake of Kamphaeng Saen young bulls

Nutrient intake	Concentrate feeding levels		SEM[1/]	*P* - value
	1.0 % BW	1.5 % BW		
GE (kJ/ $BW^{0.75}$/d)	2,274.12	2,423.35	34.20	0.0013
CP (g/ $BW^{0.75}$ /d)	10.75	13.05	0.32	<0.0001
EE (g/ $BW^{0.75}$ /d)	2.46	2.84	0.05	<0.0001
Ca (g/ $BW^{0.75}$ /d)	0.82	0.87	0.01	0.0030
P (g/ $BW^{0.75}$ /d)	0.30	0.35	0.01	<0.0001
CF (g/ $BW^{0.75}$ /d)	38.46	37.51	0.65	0.3735
NDF (g/ $BW^{0.75}$ /d)	81.10	80.61	1.25	0.9898
ADF (g/ $BW^{0.75}$ /d)	49.65	49.60	0.79	0.8037

[1/] standard error of the mean

Table 13 Effects of crude protein levels on nutrient intake of Kamphaeng Saen young bulls

Nutrient intake	Crude protein levels		SEM[1/]	*P* - value
	14 % CP	16 % CP		
GE (kJ/ $BW^{0.75}$/d)	2,317.75	2,379.73	34.20	0.2523
CP (g/ $BW^{0.75}$ /d)	11.49	12.31	0.32	<0.0001
EE (g/ $BW^{0.75}$ /d)	2.61	2.68	0.05	0.0799
Ca (g/ $BW^{0.75}$ /d)	0.84	0.86	0.01	0.2677
P (g/ $BW^{0.75}$ /d)	0.32	0.33	0.01	0.3800
CF (g/ $BW^{0.75}$ /d)	38.53	37.44	0.65	0.0717
NDF (g/ $BW^{0.75}$ /d)	80.40	81.32	1.25	0.9736
ADF (g/ $BW^{0.75}$ /d)	48.66	50.60	0.79	0.1567

[1/] standard error of the mean

4. Feed cost and cost per gain

Table 14 Effects of supplementary concentrate feeding levels on feed cost

Feed cost	Concentrate feeding level	
	1.0 % BW	1.5 % BW
Feed cost (concentrate)	2,363.73	3,823.35
Feed cost (grass)	260.33	248.48
Total feed cost (baht)	2,624.06	4,071.83
Feed cost per gain (baht/kg)	28.26	30.35

Table 15 Effects of crude protein levels on feed cost

Feed cost	Crude protein levels	
	14 % CP	16 % CP
Feed cost (concentrate)	3,116.64	3,070.44
Feed cost (grass)	251.795	257.009
Total feed cost (baht)	3,368.44	3,327.45
Feed cost per gain (baht/kg)	29.154	29.456

In the present experiment the different crude protein levels of concentrate feeding had no effects on feed cost (including concentrate and grass cost) and feed cost per gain as shown in Table 15. The different concentrate feeding levels had effects on concentrate feed cost (2,363.73 and 3,823.35 baht) and total feed cost (concentrate + grass) (2,624.06 and 4,071.83 baht) respectively. Grass cost tended to be higher with 1.0% BW concentrate feeding because grass intake was higher with that lower level of concentrate feeding. However feed cost per gain was not different between both concentrate feeding levels.

5. Simple linear regression analysis

Figure 8 and 9 demonstrate the simple linear regression analysis and equation for predicting metabolizable energy (ME) intake and CP intake from the desired ADG. ME (figure 8) was calculated from TDN by assuming that 1 kg of TDN = 3.62

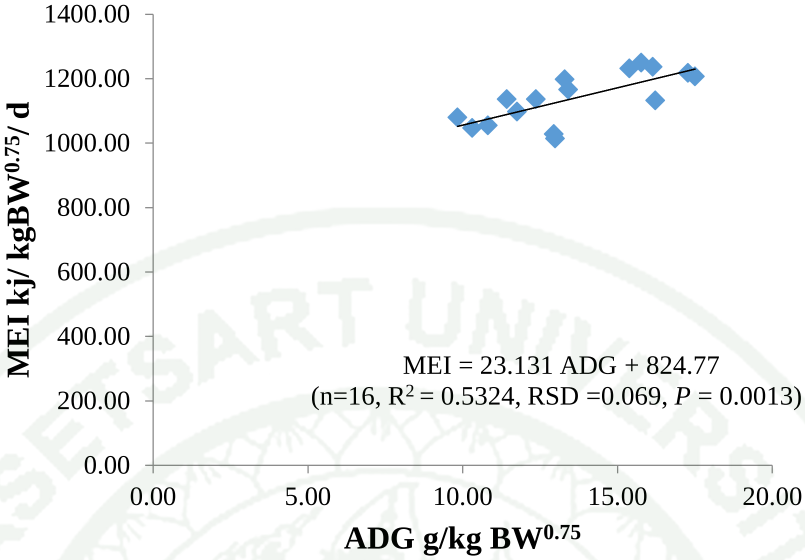


Figure 8 Simple regression for predicting MEI (kj/ kgBW$^{0.75}$/ d) from ADG (g/kg BW$^{0.75}$)

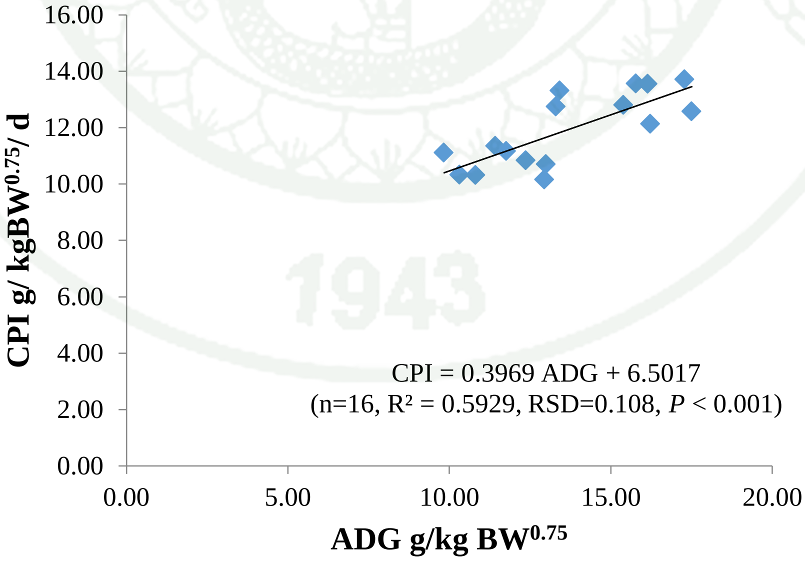


Figure 9 Simple regression for predicting CPI (g/ kgBW$^{0.75}$/ d) from ADG (g/kg BW$^{0.75}$)

Mcal of ME (Perry and Cecava, 1995). The analysis showed that the ADG of Kamphaeng Saen growing cattle could be predicted (with R^2 values for MEI = 0.5324 and CPI = 0.5929) by using the parameters.

Increasing supplementary concentrate feeding level could increase the growing performance of the Kamphaeng Saen cattle without significantly different in feed cost per gain. Conversely, grass intake would be decreased with increasing supplementary concentrate feeding level. Using with higher rumen degradable protein (RDP) level in the supplement should be matched with energy supply.

Experiment 2: Effect of TMR feeding with different energy sources (cassava chip and cassava chip plus ground corn) and different crude protein levels (12 and 14% CP) on the performances, carcass quality and production cost of finishing Kamphaeng Saen beef steers

1. **Nutrient composition of TMR diets**

The chemical composition of the 4 different TMR diets is shown in Table 16. Chemical analysis expressed that crude protein levels of each diet (11.78, 11.81, 13.95 and 13.95 % of DM) were slightly lower than expected levels. NDF contents were 29.47, 32.85, 33.62 and 32.78 (% of DM) and GE contents were 4,252.39, 4,263.92, 4,290.33 and 4,286.48 (cal/kg), respectively.

Table 16 The chemical composition of the four TMRs

Nutrient composition	cTMR12	ccTMR12	cTMR14	ccTMR14
Moisture	12.23	12.16	12.20	12.38
Crude protein (%DM)	11.78	11.81	13.95	13.95
Ether extract (%DM)	2.60	3.24	2.28	3.35
Crude fiber (%DM)	10.77	12.49	10.44	12.89
Neutral detergent fiber (%DM)	29.47	32.85	33.62	32.78
Acid detergent fiber (%DM)	20.22	21.74	21.73	21.46
Ash (%DM)	5.30	5.52	5.55	5.65
Calcium(%DM)	0.65	0.74	0.68	0.71
Phosphorus (%DM)	0.31	0.32	0.35	0.35
Gross energy (cal/kg)	4,252.39	4,263.92	4,290.33	4,286.48

2. **Finishing performance**

There was no significant interaction between two factors (different energy sources and different crude protein levels). No significant difference ($P > 0.05$) was observed between initial weight (383.92 and 382.08 kg), weight gain (130.08 and 111.67 kg), ADG (1.10, and 0.95 kg/day), FCR (8.31 and 9.77), total feed intake

(1,186.56 and 1,157.92 kg), total DMI (1,050.49 and 1,016.19 kg), DM intake/day (8.84 and 8.55 kg/day), DM intake %BW (1.97 and 1.95 %) and DM intake/day/kg $BW^{0.75}$ (90.48 and 89.19 g/day/kg $BW^{0.75}$) of the two different energy sources (cassava chip and cassava chip + ground corn), respectively (Table 17). Final BW (514.00 and 493.75 kg) was significantly different (P < 0.05) between the steers fed with two different energy sources.

Table 17 Effects of different energy sources (cassava chip and cassava chip + ground corn) on the finishing performance of Kamphaeng Saen steers

Finishing performance	Different energy sources		SEM[1/]	*P* - value
	cTMR	ccTMR		
No. of bulls	24	24	-	-
Initial BW (kg)	383.92	382.08	3.70	0.7031
Final BW (kg)	514.00	493.75	7.27	0.0336
Weight gain (kg)	130.08	111.67	6.09	0.0620
ADG (kg/d)	1.10	0.95	0.05	0.0636
Total FI (kg)	1,186.56	1,157.92	31.61	0.3759
Total DMI (kg)	1,050.49	1,016.19	27.95	0.2358
DM intake				
kg/d	8.84	8.55	0.23	0.2511
%BW	1.97	1.95	0.04	0.7512
g/$BW^{0.75}$	90.48	89.19	1.94	0.5763
FCR (kg)	9.77	8.32	0.51	0.1026

[1/] standard error of the mean

The results of different crude protein levels (12%CP and 14%CP) showed no significant effect on initial weight (378.75 and 387.25 kg), weight gain (114.75 and 127.00 kg), ADG (0.97 and 1.07 kg/day), FCR (9.47 and 8.62), total feed intake (1,166.72 and 1,177.76 kg), total DMI (1,029.72 and 1,036.95 kg), DM intake per day (8.66 and 8.73 kg/day), DM intake %BW (1.98 and 1.93 %) and DM intake/day/kg $BW^{0.75}$ (90.54 and 89.14 g/day/kg $BW^{0.75}$) respectively. However, 14% CP level was significantly (P < 0.05) higher in final BW (514.25 kg) than 12% CP level (493.50 kg). This data indicated that when we used highly rumen degradable energy sources, increase in crude protein would give better performance. In this study, the final live weight was less than normal range. Normally the cattle used to be fed in feedlot for 6-8 months until their final BW reached to (550 – 600 kg) of Kamphaeng Saen cattle (Yimmongkol, 2009).

Table 18 Effects of crude protein levels on the finishing performance of Kamphaeng Saen steers

Finishing performance	Crude protein levels		SEM[1/]	*P* - value
	12 % CP	14 % CP		
No. of bulls	24	24	-	-
Initial BW (kg)	378.75	387.25	3.70	0.0918
Final BW (kg)	493.50	514.25	7.27	0.0300
Weight gain (kg)	114.75	127.00	6.09	0.1997
ADG (kg/d)	0.97	1.07	0.05	0.1972
Total FI (kg)	1,166.72	1,177.76	31.61	0.7297
Total DMI (kg)	1,029.72	1,036.95	27.95	0.7981
DM intake				
kg/d	8.66	8.73	0.23	0.7867
%BW	1.98	1.93	0.04	0.3480
g/BW $^{0.75}$	90.54	89.14	1.94	0.5446
FCR (kg)	9.47	8.62	0.51	0.3281

[1/] standard error of the mean

In accordance with the present experiment results, feeding cTMR (containing 36% cassava chip) was significantly (20.25 kg) higher in final BW than ccTMR (containing 18% cassava chip + 18% of ground corn), even though other finishing performance such as weight gain, feed intake and feed conversion rate showed statistically no difference by feeding different energy sources. The finishing performance results on this research were a little difference with the findings of Zinn and DePeters (1991) that inclusion of 15 - 30% cassava in the diet increased feed intake and ADG and Holzer *et al.* (1997) that DM intake of the diets containing 20% and 40% cassava were 14% and 10% respectively higher than that of the control diet. In this research, weight gain and ADG tended to be higher (P = 0.0620 and 0.0636) by feeding cTMR than ccTMR, although feed intake did not show any difference. The results indicated that cassava chip had a good potential to be used as an energy source in feedlot ration.

3. Carcass composition

Table 19 Effects of different energy sources (cassava chip and cassava chip plus ground corn) on the carcass composition of Kamphaeng Saen steers

Carcass composition	different energy sources		SEM[1/]	*P* - value
	cTMR	ccTMR		
Slaughtering BW (kg)	495.42	475.83	7.31	0.0323
WCW (kg)	292.75	282.33	4.04	0.0641
CCW (kg)	290.36	279.15	4.07	0.0694
Entrails wt. (kg)	89.91	83.36	2.42	0.0555
Hide (kg)	44.48	43.88	1.12	0.7724
WCW (%)	59.18	59.34	0.37	0.7950
Entrails wt. (%)	18.11	17.47	0.32	0.2493
Hide (%)	8.96	9.25	0.20	0.4684
KPH fat (%)	5.48	5.95	0.22	0.2690

[1/] standard error of the mean

After the feeding trial, all finished steers were sent to the slaughter house to study carcass composition and quality. The effect of feeding different energy sources expressed no significant difference on WCW, CCW, entrails weight, hide and KPH fat. Slaughtering BW (495.42 and 475.83 kg) was significantly (P < 0.05) high and WCW, CCW tended to be high with the cTMR feeding group (Table 19). That was clear to be effect of high in final BW with that cTMR feeding group.

WCW (281.79 and 293.29 kg) and CCW (278.22 and 291.29 kg) were significantly ($P < 0.05$) high with higher CP level although other carcass composition results (slaughtering BW, entrails wt., hide, KPH fat) showed no differences. KPH fat tended to increase ($P = 0.0764$) with 12% CP, that would be an effect of increasing WCW and CCW without showing any difference in slaughtering BW (478.42 and 492.83 kg). Another effect would be initial BW ($P = 0.0918$) difference (378.75 and 387.25 kg) in the cattle with different crude protein levels (Table 20).

Table 20 Effects of crude protein levels (12 and 14 % CP) on the carcass composition of Kamphaeng Saen steers

Carcass composition	Crude protein levels		SEM[1/]	*P* - value
	12 % CP	14 % CP		
Slaughtering BW (kg)	478.42	492.83	7.31	0.1029
WCW (kg)	281.79	293.29	4.04	0.0434
CCW (kg)	278.22	291.29	4.07	0.0376
Entrails wt. (kg)	85.85	87.42	2.42	0.6267
Hide (kg)	43.20	45.17	1.12	0.3496
WCW (%)	58.97	59.54	0.37	0.3635
Entrails wt. (%)	17.87	17.71	0.32	0.7702
Hide (%)	9.03	9.18	0.20	0.7100
KPH fat (%)	6.11	5.33	0.22	0.0764

[1/] standard error of the mean

4. Meat quality

The carcass quality of the Kamphaeng Saen finished steers did not show any difference ($P > 0.05$). The results stated that feeding TMR with different energy sources (cTMR and ccTMR) had no effects on pH (at 1 hr and 24 hr post-mortem), temperature (at 1 hr and 24 hr post- mortem), meat colour (expressed as L*, a*, b*), loin eye area, back fat thickness, marbling score and water holding capacity (chilling loss, drip loss and grilling loss). The similar results were also attained by the cattle feeding different crude protein levels (12 % CP and 14 % CP) showing different crude protein levels did not influence on carcass quality (Table 21 and 22).

Table 21 Effects of different energy sources (cassava chip and cassava chip plus ground corn) on the carcass quality of Kamphaeng Saen steers

Carcass quality	different energy sources		SEM[1]	*P* – value
	cTMR	ccTMR		
pH 1hr	6.73	6.58	0.05	0.1624
Temp 1hr (˚C)	38.56	39.37	0.30	0.1635
pH 24hr	5.47	5.48	0.43	0.9278
Temp 24hr (˚C)	7.34	7.00	0.67	0.6912
L*	47.22	46.06	0.95	0.3952
a*	16.90	16.21	0.43	0.4255
b*	17.58	16.61	0.40	0.1615
Chilling loss (%)	0.66	1.28	0.20	0.1645
Grilling loss (%)	31.84	29.58	0.97	0.1043
Drip loss (%)	3.65	3.90	0.38	0.5755
Tenderness (kg)	1.61	1.89	0.09	0.2547
Back fat thickness (cm)	1.24	1.47	2.28	0.2885
Loin eye area (cm^2)	85.10	83.67	0.15	0.7792
Marbling score	1.92	2.17	0.34	0.4486

[1/] standard error of the mean

The pH and carcass temperature changes at 1 hr and 24 hr post-mortem were found to be regular and there were no significant differences by feeding different energy sources (cTMR and ccTMR) and different crude protein levels (12 and 14 % CP). Final pH values in both groups is at the lower point of normal range (5.5 – 5.8) (Silva *et al.*, 1999) and ultimate pH level (5.5 - 6.7) (Silva *et al.*, 1999). But no DFD or PSE carcasses were identified in this study. No significant difference in chilling loss, drip loss and grilling loss showed that there was no effect on water holding capacity of the carcasses by feeding different energy sources and crude protein levels.

Meat colour (L*, a*, b*), shear force, back fat thickness and loin eye area also showed no significant effects (P > 0.05) between two different TMRs with different energy sources (Table 21). Carcass quality results of the current study agreed the other studies on the different energy sources of Yimmongkol *et al.* (2009) and Laorodphan *et al.* (2012) which resulted no significant effects on meat quality.

Table 22 Effects of different crude protein levels (12 and 14 % CP) on the carcass quality of Kamphaeng Saen steers

Carcass quality	Crude protein levels		SEM[1/]	*P* – value
	12 % CP	14 % CP		
pH 1hr	6.66	6.65	0.05	0.8858
Temp 1hr (˚C)	38.92	39.01	0.30	0.8702
pH 24hr	5.42	5.53	0.43	0.1984
Temp 24hr (˚C)	7.13	7.21	0.67	0.9253
L*	47.41	45.87	0.95	0.2598
a*	16.55	16.56	0.43	0.9917
b*	17.23	16.97	0.40	0.6995
Chilling loss (%)	0.83	1.11	0.20	0.5183
Grilling loss (%)	30.98	30.44	0.97	0.6879
Drip loss (%)	3.77	3.78	0.38	0.9830
Tenderness (kg)	1.92	1.57	0.09	0.1659
Back fat thickness (cm)	1.48	1.22	2.28	0.2226
Loin eye area (cm^2)	81.90	86.87	0.15	0.3383
Marbling score	2.08	2.00	0.34	0.7989

[1/] standard error of the mean

5. Production cost

Carcass income was higher with cTMR feeding group than ccTMR feeding group (46,964.00 and 44,122.00 baht). Higher income was depending on the carcass price and chilled carcass weight, because we calculated the carcass income by multiplying carcass price and CCW. By KU beef carcass pricing system, higher price carcass must have younger age at slaughter, high marbling score, high dressing percentage. However, carcass price shows no highly difference between cTMR and ccTMR feeding groups and the high carcass income must come from CCW because the CCW in cTMR feeding group tended to be higher than ccTMR group (Table 23).

Table 23 Effects of different energy sources (cassava chip and cassava chip plus ground corn) on the production cost (per head)

Production cost	Different energy sources	
	cTMR	ccTMR
Carcass price (baht/kg)	161.67	157.75
Carcass income (baht)	46,964.00	44,122.00
Feed price (baht/kg)	7.52	7.60
Total feed cost (baht)	8,925.70	8,799.50
feed cost per day (baht/day)	75.08	74.08
Feed cost /kg of gain (baht/kg)	70.66	84.41
Cattle price (baht/kg)	80.00	80.00
Cattle cost (baht)	30,713.30	30,566.70
Management cost (baht)	1,750.00	1,750.00
Total production cost (baht)	41,389.00	41,116.20
Production cost/ kg of gain (baht/kg)	330.27	396.48
Profit/head (baht)	5,575.00	3,006.00
Profit (%)	13.82	7.56

Feed price of ccTMR (7.60 baht) was higher than cTMR (7.52 baht). That would be a result from inclusion of ground corn in ccTMR (containing 18% cassava chip + 18% of ground corn). During the experiment, ground corn and cassava chip prices were 10.5 and 8.8 baht/kg, respectively. Feed cost per gain was lower in cTMR feeding group and profit per head and profit percentage were also higher in cTMR feeding group. Using cassava chip as an energy source could be cheaper in production cost and better in profit (Table 24).

Table 24 Effects of different crude protein levels (12 and 14 % CP) on the production cost (per head)

Production cost	Crude protein levels	
	12 % CP	14 % CP
Carcass price/kg (baht/kg)	158.75	160.67
Carcass income (baht)	44,260.00	46,826.00
Feed price (baht/kg)	7.36	7.76
Total feed cost (baht)	8,586.90	9,138.30
Feed cost per day (baht/day)	72.23	76.92
Feed cost /kg of gain (baht/kg)	79.08	75.99
Cattle price (baht/kg)	80.00	80.00
Cattle cost (baht)	30,300.00	30,980.00
Management cost (baht)	1,750.00	1,750.00
Total production cost (baht)	40,636.90	41,868.30
Production cost/ kg of gain (baht/kg)	323.28	405.65
Profit/head (baht)	3,623.00	4,958.00
Profit (%)	9.14	12.23

The results of different crude protein levels (12 % CP and 14 % CP) stated total feed cost (8,586.90 and 9,138.30 baht), feed cost/ day (72.23 and 76.92 baht) and total production cost (40,636.90 and 41,868.30 baht). Feed price was higher with high crude protein level (14 % CP) feeding group. In this experiment, soy bean meal (true protein source) and urea (NPN source) were used as a major protein source in both 12 and 14 % CP TMRs as shown in Table 7. Although the carcass price showed no highly difference between two different crude protein levels, carcass income was higher in 14 % CP TMR feeding group since the CCW was significantly higher in the group. Nevertheless, feed cost per kg of gain, profit per head and profit percentage did not show highly difference between two groups

.

CONCLUSIONS AND RECOMMENDATIONS

The results of the research could be summarized as follow:

1. Increasing supplementary concentrate feeding level could increase the growing performance.

2. Grass intake would decrease with increasing supplementary concentrate feeding level.

3. Concentrate using with higher rumen degradable protein level in the supplement should be matched with energy supply.

4. Even though increasing supplementary concentrate feeding level increases the feed cost, there was no significant difference in feed cost per gain.

5. Totally replacing ground corn with cassava chip TMR showed better finishing performance, higher income, and cheaper price than cassava chip plus ground corn TMR without affecting on meat quality.

6. TMR with the 14 % CP has enough potential to show higher finishing weight, and carcass weight but higher feed cost than 12 % CP TMR. However, feed cost per gain was not significantly different and profit tended to be higher in 14% CP feeding group.

7. Cassava chip has enough potential to be used as an energy source in TMR for feedlot cattle because of its cheaper price and market availability.

LITERATURE CITED

Andersen, H. R. 1975. The influence of slaughter weight and level of feeding on growth rate, feed conversion and carcass composition of bulls. **Livest. Prod. Sci.** 2(4): 341-355.

Andersen, H. R., K. L. Ingvartsen and S. Klastrup. 1984. Influence of energy level, weight at slaughter and castration on carcass quality in cattle. **Livest. Prod. Sci.** 11(6): 571-586.

Arroquy, J. I., R. C. Cochran, M. Villarreal, T. A. Wickersham, D. A. Llewellyn, E. C. Titgemeyer, T. G. Nagaraja, D. E. Johnson and D. Gnad. 2004a. Effect of level of rumen degradable protein and type of supplemental non-fiber carbohydrate on intake and digestion of low-quality grass hay by beef cattle. **Anim. Feed Sci. and Tech.** 115(1–2): 83-99.

Arroquy, J. I., R. C. Cochran, T. A. Wickersham, D. A. Llewellyn, E. C. Titgemeyer, T. G. Nagaraja and D. E. Johnson. 2004b. Effects of type of supplemental carbohydrate and source of supplemental rumen degradable protein on low quality forage utilization by beef steers. **Anim. Feed Sci. and Tech.** 115(3–4): 247-263.

ASEAN. 2010. **ASEAN Statistical Yearbook 2010**. Jakarta: ASEAN Secretariat, December 2010.

Baker, M. and R. E. Mikesell. 2011. **Animal Science Biology & Technology**. Delmar Cengage Learning. Australia; United States.

Bartley, E. E., A. D. Davidovich, G. W. Barr, G. W. Griffel, A. D. Dayton, C. W. Deyoe and R. M. Bechtle. 1976. Ammonia toxicity in cattle. I. Rumen and blood changes associated with toxicity and treatment methods. **J. Anim. Sci.** 43(4): 835-841.

Baumann, T. A., G. P. Lardy, J. S. Caton and V. L. Anderson. 2004. Effect of energy source and ruminally degradable protein addition on performance of lactating beef cows and digestion characteristics of steers. **J. Anim. Sci.** 82(9): 2667-2678.

Beauchemin, K. A., W. Z. Yang and L. M. Rode. 2001. Effects of barley grain processing on the site and extent of digestion of beef feedlot finishing diets. **J. Anim. Sci.** 79(7): 1925-36.

Berg, R. T. and R. M. Butterfield. 1976. **New Concepts of Cattle Growth**. Sydney University Press. Sydney.

BRDC. 2011. **kamphaeng Saen Beef Breed**. 3rd ed.: Buffalo and Beef Production Research and Development Center.

Caplis, J., M. G. Keane, A. P. Moloney and F. B. O'mara. 2005. Effects of supplementary concentrate level with grass silage, and separate or total mixed ration feeding, on performance and carcass traits of finishing steers. **Ir. J. Agric. Food Res.** 44: 27-43.

Caton, J. S. and D. V. Dhuyvetter. 1997. Influence of energy supplementation on grazing ruminants: requirements and responses. **J. Anim. Sci.** 75(2): 533-42.

Chanjula, P., M. Wanapat, C. Wachirapakorn, S. Uriyapongson and P. Rowlinson. 2003. Ruminal degradability of tropical feeds and their potential use in ruminant diets. **Asian-Aust. J. Anim. Sci.** 16: 211-216.

CIE. 1978. **Recommendations on Uniform Color Spaces, Color-Difference Equations, Psychometric Color Terms** Bureau Central de la CIE. Paris, France.

Colorado. **Impacts of Ammonia**: Colorado State University. Available source: http://ammoniabmp.colostate.edu/link%20pages/impacts%20of%20ammonia. html, April 3, 2013.

Delcurto, T., R. C. Cochran, D. L. Harmon, A. A. Beharka, K. A. Jacques, G. Towne and E. S. Vanzant. 1990. Supplementation of dormant tall grass-prairie forage: I. Influence of varying supplemental protein and (or) energy levels on forage utilization characteristics of beef steers in confinement. **J. Anim. Sci.** 68(2): 515-31.

Forero, O., F. N. Owens and K. S. Lusby. 1980. Evaluation of slow-release urea for winter supplementation of lactating range cows. **J. Anim. Sci.** 50(3): 532-538.

French, P., E. G. O'riordan, F. J. Monahan, P. J. Caffrey, M. Vidal, M. T. Mooney, D. J. Troy and A. P. Moloney. 2000. Meat quality of steers finished on autumn grass, grass silage or concentrate-based diets. **Meat Sci.** 56(2): 173-180.

Galyean, M. L. 1996. Protein levels in beef cattle finishing diets: industry application, university research, and systems results. **J. Anim. Sci.** 74(11): 2860-70.

Gillespie, J. R. and F. B. Flanders. 2010. **Modern Livestock and Poultry Production**. Delmar Cengage Learning. Clifton Park, NY.

Gonda, H. L., M. Emanuelson and M. Murphy. 1996. The effect of roughage to concentrate ratio in the diet on nitrogen and purine metabolism in dairy cows. **Anim. Feed Sci. and Tech.** 64(1): 27-42.

Grandin, T. **Livestock Behaviour, Design of Facilities and Humane Slaughter**. Available source: http://www.grandin.com/meat/cattle/cattle.meat.html, April 3, 2013.

Grigsby, K. N., M. S. Kerley, J. A. Paterson and J. C. Weigel. 1993. Combinations of starch and digestible fiber in supplements for steers consuming a low-quality bromegrass hay diet. **J. Anim. Sci.** 71(4): 1057-64.

Hall, M. B. and G. B. Huntington. 2008. Nutrient synchrony: Sound in theory, elusive in practice. **J. Anim. Sci.** 86(14 suppl): E287-E292.

Heldt, J. S., R. C. Cochran, C. P. Mathis, B. C. Woods, K. C. Olson, E. C. Titgemeyer, T. G. Nagaraja, E. S. Vanzant and D. E. Johnson. 1999a. Effects of level and source of carbohydrate and level of degradable intake protein on intake and digestion of low-quality tallgrass-prairie hay by beef steers. **J. Anim. Sci.** 77(10): 2846-54.

Heldt, J. S., R. C. Cochran, G. L. Stokka, C. G. Farmer, C. P. Mathis, E. C. Titgemeyer and T. G. Nagaraja. 1999b. Effects of different supplemental sugars and starch fed in combination with degradable intake protein on low-quality forage use by beef steers. **J. Anim. Sci.** 77(10): 2793-802.

Helmer, L. G. and E. E. Bartley. 1971. Progress in the utilization of urea as a protein replacer for ruminants. A review. **J. Dairy Sci.** 54(1): 25-51.

Herren, R. V. 2010. **The Art and Science of Livestock Evaluation**. Delmar. Clifton Park, NY.

Herrera-Saldana, R., R. Gomez-Alarcon, M. Torabi and J. T. Huber. 1990. Influence of synchronizing protein and starch degradation in the rumen on nutrient utilization and microbial protein synthesis. **J. Dairy Sci.** 73(1): 142-148.

Holzer, Z., Y. Aharoni, V. Lubimov and A. Brosh. 1997. The feasibility of replacement of grain by tapioca in diets for growing-fattening cattle. **Anim. Feed Sci. and Tech.** 64(2–4): 133-141.

Honikel, K. O. 2004. **Muscle Development of Livestock Animals: Physiology, Genetics and Meat Quality**. CABI Publishing. Cambridge, MA.

Hoover, W. H. 1986. Chemical factors involved in ruminal fiber digestion. **J. Dairy Sci.** 69(10): 2755-2766.

Horrocks, R. D. and J. F. Vallentine. 1999. **Harvested Forages**. Academic Press. San Diego [etc.].

Huff-Lonergan, E. and S. M. Lonergan. 2005. Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. **Meat Sci.** 71(1): 194-204.

Indurain, G., T. R. Carr, M. V. Goñi, K. Insausti and M. J. Beriain. 2009. The relationship of carcass measurements to carcass composition and intramuscular fat in Spanish beef. **Meat Sci.** 82(2): 155-161.

Johnson, R. R. 1976. Influence of carbohydrate solubility on non-protein nitrogen utilization in the ruminant. **J. Anim. Sci.** 43(1): 184-191.

Jouany, J. P. 1991. **Rumen Microbial Metabolism and Ruminant Digestion**. Institut national de la recherche agronomique. Paris.

Kaps, M. and W. R. Lamberson. 2004. **Biostatistics for Animal Science**. CABI Pub. Wallingford, Oxfordshire; Cambridge, MA.

Keane, M. G. and M. J. Drennan. 2009. Effects of supplementary concentrate level in winter, and subsequent finishing on pasture or indoors, on performance and carcass traits of Holstein–Friesian, Aberdeen Angus×Holstein–Friesian and Belgian Blue×Holstein–Friesian steers. **Livest. Sci.** 121(2–3): 250-258.

Keane, M. G., M. J. Drennan and A. P. Moloney. 2006. Comparison of supplementary concentrate levels with grass silage, separate or total mixed ration feeding, and duration of finishing in beef steers. **Livest. Sci.** 103(1–2): 169-180.

Khy, V., P. Prucsasri, C. Kanthapanit and P. Chtwachirawong. 2000. A comparison of growth, feed efficiency and carcass characteristics of Kamphaeng Saen steers fed two TMR fiber sources during two different feeding period. **Kasetsart J. (Nat. Sci.)** 34: 216-226.

Klevesahl, E. A., R. C. Cochran, E. C. Titgemeyer, T. A. Wickersham, C. G. Farmer, J. I. Arroquy and D. E. Johnson. 2003. Effect of a wide range in the ratio of supplemental rumen degradable protein to starch on utilization of low-quality, grass hay by beef steers. **Anim. Feed Sci. and Tech.** 105(1–4): 5-20.

Koohmaraie, M. 1996. Biochemical factors regulating the toughening and tenderization processes of meat. **Meat Sci.** 43, Supplement 1(0): 193-201.

Koohmaraie, M. and G. H. Geesink. 2006. Contribution of postmortem muscle biochemistry to the delivery of consistent meat quality with particular focus on the calpain system. **Meat Sci.** 74(1): 34-43.

Koohmaraie, M., M. P. Kent, S. D. Shackelford, E. Veiseth and T. L. Wheeler. 2002. Meat tenderness and muscle growth: is there any relationship? **Meat Sci.** 62(3): 345-352.

Köster, H. H., R. C. Cochran, E. C. Titgemeyer, E. S. Vanzant, T. G. Nagaraja, K. K. Kreikemeier and G. St Jean. 1997. Effect of increasing proportion of supplemental nitrogen from urea on intake and utilization of low-quality, tallgrass-prairie forage by beef steers. **J. Anim. Sci.** 75(5): 1393-9.

Lacourt, A. and P. V. Tarrant. 1985. Glycogen depletion patterns in myofibres of cattle during stress. **Meat Sci.** 15(2): 85-100.

Laorodphan, N., S. Jaturasitha, N. Chongkasikit, C. Phatsara, V. Sirinupongsanun, S. Yammuen-Art, A. Waritthitham and C. Mikled. Effect of feeding dried cassava pulp on meat quality in feedlot beef cattle, pp. 1099-1105. **15th AAAP Animal Science Congress**; Thammasat University, Rangsit Campus, Thailand.

Loerch, S. C. 1990. Effects of feeding growing cattle high-concentrate diets at a restricted intake on feedlot performance. **J. Anim. Sci.** 68(10): 3086-95.

Lowman, B. G. and M. Lewis. 1996. **Feeding and Management of Intensively Reared Bulls: Conventional Compared with Organic**. Nottingham University Press. Loughborough.

Maher, S. C., A. M. Mullen, D. J. Buckley, J. P. Kerry and A. P. Moloney. 2005. The influence of biochemical differences on the variation in tenderness of M. *longissimus dorsi* of Belgian Blue steers managed homogenously pre and post-slaughter. **Meat Sci.** 69(2): 215-224.

Majak, W. and K. J. Cheng. 1984. Cyanogenesis in bovine rumen fluid and pure cultures of rumen bacteria. **J. Anim. Sci.** 59: 784-790.

Manninen, M., L. Jauhiainen, M. Ruusunen, T. Soveri, N. Koho and R. Pösö. 2010. Effects of concentrate type and level on the performance and health of finishing Hereford bulls given a grass silage-based diet and reared in cold conditions. **Livest. Sci.** 127(2–3): 227-237.

Mansathit, J., C. Promkot and O. Pungchompoo. 2012. Improvement of cassava chips and urea utilization in cattle by griding cassava chip and increase urea level in ration, pp. **Proceedings of the 15th AAAP Animal Science Congress**.

Marino, R., M. Albenzio, A. Girolami, A. Muscio, A. Sevi and A. Braghieri. 2006. Effect of forage to concentrate ratio on growth performance, and on carcass and meat quality of Podolian young bulls. **Meat Sci.** 72(3): 415-424.

Mcveigh, J. M., P. V. Tarrant and M. G. Harrington. 1982. Behavioral stress and skeletal muscle glycogen metabolism in young bulls. **J. Anim. Sci.** 54(4): 790-795.

Mialon, M. M., C. Martin, F. Garcia, J. B. Menassol, H. Dubroeucq, I. Veissier and D. Micol. 2008. Effects of the forage-to-concentrate ratio of the diet on feeding behaviour in young Blond d'Aquitaine bulls. **Anim.** 2(11): 1682-1691.

Muchenje, V., K. Dzama, M. Chimonyo, P. E. Strydom, A. Hugo and J. G. Raats. 2009. Some biochemical aspects pertaining to beef eating quality and consumer health: a review. **Food Chem.** 112(2): 279-289.

Muir, P. D., J. M. Deaker and M. D. Bown. 1998. Effects of forage- and grain-based feeding systems on beef quality: A review. **New Zeal. J. Agr. Res.** 41(4): 623-635.

Muzanila, Y. C., J. G. Brennan and R. D. King. 2000. Residual cyanogens, chemical composition and aflatoxins in cassava flour from Tanzanian villages. **Food Chem.** 70(1): 45-49.

Nagaraja, T. G., C. J. Newbold, C. J. Vannevel and D. I. Demeyer. 1997. Modification of the ruminal fermentation pattern, pp. 525-530. In: P. N. Hobson and C. S. Stewart, eds. **The Rumen Microbial Ecosystem**. Blakie academic and professional. London , New York.

Nocek, J. E. 1997. Bovine acidosis: Implications on laminitis. **J. Dairy Sci.** 80(5): 1005-1028.

NRC. 2000. **Nutrient Requirements of Beef Cattle**. National Academy Press. Washington, D.C.

Olson, K. C., R. C. Cochran, T. J. Jones, E. S. Vanzant, E. C. Titgemeyer and D. E. Johnson. 1999. Effects of ruminal administration of supplemental degradable intake protein and starch on utilization of low-quality warm-season grass hay by beef steers. **J. Anim. Sci.** 77(4): 1016-25.

Ovenell, K. H., K. S. Lusby, G. W. Horn and R. W. Mcnew. 1991. Effects of lactational status on forage intake, digestibility, and particulate passage rate of beef cows supplemented with soybean meal, wheat middlings, and corn and soybean meal. **J. Anim. Sci.** 69(6): 2617-23.

Parish, J. A. and J. D. Rhinehart. **Protein in Beef Cattle Diets** Extension Service of Mississippi State University: Mississippi State University. Available source:

http://www.thebeefsite.com/articles/1542/protein-in-beef-cattle-diets, April 3, 2013.

Perry, T. W. and M. J. Cecava. 1995. **Beef Cattle Feeding and Nutrition**. Academic Press. San Diego, Calif.

Plaizier, J. C., D. O. Krause, G. N. Gozho and B. W. Mcbride. 2008. Subacute ruminal acidosis in dairy cows: The physiological causes, incidence and consequences. **Vet. J.** 176(1): 21-31.

Pordomingo, A. J., J. D. Wallace, A. S. Freeman and M. L. Galyean. 1991. Supplemental corn grain for steers grazing native rangeland during summer. **J. Anim. Sci.** 69(4): 1678-87.

Priolo, A., D. Micol and J. Agabriel. 2001. Effects of grass feeding systems on ruminant meat colour and flavour. A review. **Anim. Res.** 50(3): 185-200.

Raungprim, T., P. Innurak, P. Skunmun, R. Phungchai, K. Kaewsomprasong, S. Majarune and W. Maitreejet. Performance testing of Kamphaeng Saen synthetic Thai beef cattle breed, pp. 26-30. **the 15th AAAP Animal Science Congress**; Thammasat University, Rangsit Campus, Thailand.

Ravindran, V. 1992. Preparation of cassava leaf products and their use as animal feeds. **FAO animal production and health paper (Rome, Italy: Food and Agriculture Organization of the United Nations)** 95: 111-125.

Razminowicz, R. H., M. Kreuzer and M. R. L. Scheeder. 2006. Quality of retail beef from two grass-based production systems in comparison with conventional beef. **Meat Sci.** 73(2): 351-361.

Robinson, P. H. and R. E. Mcqueen. 1994. Influence of supplemental protein source and feeding frequency on rumen fermentation and performance in dairy cows. **J. Dairy Sci.** 77(5): 1340-1353.

Robson, A. E. 1995. Effects of forage to concentrate ratio in the diet and protein intake on the performance and carcass composition of beef heifers. **J. Agr. Sci.** 125(01): 125-135.

Rotger, A., A. Ferret, S. Calsamiglia and X. Manteca. 2006. Effects of nonstructural carbohydrates and protein sources on intake, apparent total tract digestibility, and ruminal metabolism in vivo and in vitro with high-concentrate beef cattle diets. **J. Anim. Sci.** 84(5): 1188-1196.

Ruiz, T. M., E. Bernal, C. R. Staples, L. E. Sollenberger and R. N. Gallaher. 1995. Effect of dietary neutral detergent fiber concentration and forage source on performance of lactating cows. **J. Dairy Sci.** 78(2): 305-319.

Rush, I. G., R. R. Johnson and T. R. 1976. Evaluation of beef cattle range supplements containing urea and biuret. **J. Anim. Sci.** 42: 1297.

Russell, J. B. 2002. **Rumen Microbiology and Its Role in Ruminant Nutrition**. James B. Russell. Ithaca, N.Y.

Sanson, D. W., D. C. Clanton and I. G. Rush. 1990. Intake and digestion of low-quality meadow hay by steers and performance of cows on native range when fed protein supplements containing various levels of corn. **J. Anim. Sci.** 68(3): 595-603.

Shabi, Z., A. Arieli, I. Bruckental, Y. Aharoni, S. Zamwel, A. Bor and H. Tagari. 1998. Effect of the synchronization of the degradation of dietary crude protein and organic matter and feeding frequency on ruminal fermentation and flow of digesta in the abomasum of dairy cows. **J. Dairy Sci.** 81(7): 1991-2000.

Shriver, B. J., W. H. Hoover, J. P. Sargent, R. J. Crawford Jr and W. V. Thayne. 1986. Fermentation of a high concentrate diet as affected by ruminal pH and digesta flow. **J. Dairy Sci.** 69(2): 413-419.

Silva, J. A., L. Patarata and C. Martins. 1999. Influence of ultimate pH on bovine meat tenderness during ageing. **Meat Sci.** 52(4): 453-459.

Sommart, K., D. S. Parker, P. Rowlinson and M. Wanapat. 2000. Fermentation characteristics and microbial protein synthesis in an in vitro system using cassava, rice straw and dried ruzi grass as substrates. **Asian-Aust. J. Anim. Sci.** 13(8): 1084-1093.

Steen, R. W. J. and D. J. Kilpatrick. 1995. Effects of plane of nutrition and slaughter weight on the carcass composition of serially slaughtered bulls, steers and heifers of three breed crosses. **Livest. Prod. Sci.** 43(3): 205-213.

Stolowski, G. D., B. E. Baird, R. K. Miller, J. W. Savell, A. R. Sams, J. F. Taylor, J. O. Sanders and S. B. Smith. 2006. Factors influencing the variation in tenderness of seven major beef muscles from three Angus and Brahman breed crosses. **Meat Sci.** 73(3): 475-483.

Thang, C. M., I. Ledin and J. Bertilsson. 2010. Effect of using cassava products to vary the level of energy and protein in the diet on growth and digestibility in cattle. **Livest. Sci.** 128(1–3): 166-172.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. **J. Dairy Sci.** 74(10): 3583-3597.

Vestergaard, M., N. Oksbjerg and P. Henckel. 2000a. Influence of feeding intensity, grazing and finishing feeding on muscle fibre characteristics and meat colour of semitendinosus, *longissimus dorsi* and *supraspinatus* muscles of young bulls. **Meat Sci.** 54(2): 177-185.

Vestergaard, M., M. Therkildsen, P. Henckel, L. R. Jensen, H. R. Andersen and K. Sejrsen. 2000b. Influence of feeding intensity, grazing and finishing feeding on meat and eating quality of young bulls and the relationship between muscle fibre characteristics, fibre fragmentation and meat tenderness. **Meat Sci.** 54(2): 187-195.

Vetter, J. 2000. Plant cyanogenic glycosides. **Toxicon** 38(1): 11-36.

Walsh, K., P. O'kiely, A. P. Moloney and T. M. Boland. 2008. Intake, performance and carcass characteristics of beef cattle offered diets based on whole-crop wheat or forage maize relative to grass silage or *ad libitum* concentrates. **Livest. Sci.** 116(1–3): 223-236.

Wanapat, M. 2003. **Manipulation of Cassava Cultivation and Utilization to Improve Protein to Energy Biomass for Livestock Feeding in the Tropics**. Asian-Autralasian Association of Animal Production Societies. Seoul, COREE, REPUBLIQUE DE.

Wanapat, M. 2009. Potential uses of local feed resources for ruminants. **Trop. Anim. Health Pro.** 41(7): 1035-1049.

Wanapat, M. and S. Khampa. 2007. Effect of levels of supplementation of concentrate containing high levels of cassava chip on rumen ecology, microbial N supply and digestibility of nutrients in beef cattle. **Asian-Aust. J. Anim. Sci.** 20: 75-81.

Watanabe, A., C. C. Daly and C. E. Devine. 1996. The effects of the ultimate pH of meat on tenderness changes during ageing. **Meat Sci.** 42(1): 67-78.

Webb, D. W., E. E. Bartley and R. M. Meyer. 1972. A comparison of nitrogen metabolism and ammonia toxicity from ammonium acetate and urea in cattle. **J. Anim. Sci.** 35(6): 1263-1270.

Wheeler, T. L. and M. Koohmaraie. 1991. A modified procedure for simultaneous extraction and subsequent assay of calcium-dependent and lysosomal protease systems from a skeletal muscle biopsy. **J. Anim. Sci.** 69(4): 1559-65.

Yimmongkol, S. 2009. **Research and Development Projects on Improvement of the Potential Use of Dried Cassava Pulp and Cassava Leaf Meal in Concentrate of Feedlot Cattle.** Ph. D. Thesis. Kasetsart University. p. 5-7.

Yimmongkol, S., L. Boonek and S. Juttupornpong. 2009. Effects of dried cassava pulp as a main source of energy in concentrate on growth performance, carcass composition, economic return and some beef eating qualities of feedlot cattle. **Songklanakarin J. Sci. Technol.** 31 (4): 389-394.

Zagrobelny, M., S. Bak, A. V. Rasmussen, B. Jørgensen, C. M. Naumann and B. Lindberg Møller. 2004. Cyanogenic glucosides and plant–insect interactions. **Phytochemistry** 65(3): 293-306.

Zhang, S. X., M. M. Farouk, O. A. Young, K. J. Wieliczko and C. Podmore. 2005. Functional stability of frozen normal and high pH beef. **Meat Sci.** 69(4): 765-772.

Zinn, R. A. and E. J. Depeters. 1991. Comparative feeding value of tapioca pellets for feedlot cattle. **J. Anim. Sci.** 69(12): 4726-33.

APPENDIX

Appendix figure 1 Kamphaeng Saen beef cattle

Appendix figure 2 Kamphaeng Saen beef cattle fed on para grass (*Brachiaria mutica*) (left) and transporting to slaughter house (right)

Appendix figure 3 Slaughtering (left) Chilling for 14 days (right)

Appendix figure 4 Measuring back fat thickness (left) and preparing for meat quality tests (right)

Appendix figure 5 Taking meat colour measurement (left) and measuring meat tenderness (right)

Appendix Table 1 Effects of supplementary concentrate feeding levels and protein levels on the performance of Kamphaeng Saen young bulls (in two periods)

Performance	Concentrate feeding levels		*P* - value	CP levels		*P* - value	SEM[1/]	C*P[2/]
	1.0% BW	1.5% BW		CP14%	CP16%			
No. of bulls	8	8	-	8	8	-	-	-
Initial BW (kg)	211.00	214.36	-	215.75	209.63	-	-	-
Final BW (kg)								
(0-66 day)	265.38	291.38	0.0087	278.38	278.38	0.2746	10.41	0.4617
(67-126 day)	304.63	349.25	0.0002	331.00	322.88	0.9495	11.17	0.9913
(0-126 day)	304.63	349.25	0.0003	331.00	322.88	0.0499	11.17	0.2001
ADG (kg)								
(0-66 day)	0.82	1.17	0.0087	0.95	1.04	0.2746	0.07	0.4617
(67-126 day)	0.65	0.96	0.0004	0.78	0.74	0.0460	0.05	0.1814
(0-126 day)	0.74	1.07	0.0003	0.91	0.90	0.7590	0.05	0.8257
FCR								
(0-66 day)	9.58	7.31	0.0130	8.75	8.14	0.3885	0.46	0.3410
(67-126 day)	15.02	11.07	0.0140	11.42	14.67	0.0300	1.02	0.0778
(0-126 day)	11.28	8.88	0.0058	9.93	10.23	0.6381	0.42	0.8369

Appendix Table 1 (Continued)

Performance	Concentrate feeding levels		*P* - value	CP levels		*P* - value	SEM[1/]	C*P[2/]
	1.0% BW	1.5% BW		CP14%	CP16%			
Daily DM intake (kg/d)								
(0-66 day)	7.48	8.40	<0.0001	7.92	7.96	0.2136	0.18	0.7219
(67-126 day)	9.10	10.57	<0.0001	9.82	9.85	0.4727	0.24	0.7782
(0-126 day)	9.10	10.57	<0.0001	9.82	9.85	0.4727	0.21	0.4848
Daily DM intake (% BW/d)								
(0-66 day)	3.18	3.35	0.0075	3.23	3.30	0.6619	0.07	0.4076
(67-126 day)	3.24	3.32	0.1290	3.24	3.31	0.7749	0.07	0.5996
(0-126 day)	3.24	3.37	0.0004	3.25	3.36	0.0640	0.07	0.8103
Daily concentrate DM intake (kg/d)								
(0-66 day)	2.16	3.38	<0.0001	2.72	2.82	0.6525	0.18	0.7219
(67-126 day)	2.55	4.26	<0.0001	3.44	3.37	0.7371	0.25	0.7782
(0-126 day)	2.35	3.80	0.0002	3.12	3.03	0.1922	0.21	0.4848

Appendix Table 1 (Continued)

Performance	Concentrate feeding levels		*P* - value	CP levels		*P* - value	SEM[1/]	C*P[2/]
	1.0% BW	1.5% BW		CP14%	CP16%			
Daily concentrate DM intake (% BW/d)								
(0-66 day)	0.91	1.34	<0.0001	1.13	1.11	0.0896	0.06	0.8799
(67-126 day)	0.90	1.33	<0.0001	1.11	1.11	0.9174	0.06	0.9976
(0-126 day)	0.91	1.35	<0.0001	1.13	1.13	0.9610	0.06	0.2085
Daily grass intake (kg/d)								
(0-66 day)	5.32	5.02	0.0163	5.10	5.24	0.1572	0.08	0.5336
(67-126 day)	6.55	6.31	0.1668	6.38	6.48	0.5257	0.08	0.5956
(0-126 day)	5.90	5.63	0.0379	5.71	5.83	0.4048	0.08	0.5046
Daily grass intake (% BW/d)								
(0-66 day)	2.27	2.01	0.0015	2.09	2.19	0.4216	0.07	0.3818
(67-126 day)	2.34	1.99	0.0009	2.13	2.20	0.7678	0.08	0.5968
(0-126 day)	2.33	2.02	0.0249	2.23	2.12	0.0634	0.08	0.9000

[1/] standard error of the mean
[2/] interaction between two factors

Appendix Table 2 Effects of supplementary concentrate feeding levels and protein levels on nutrient intake of Kamphaeng Saen young bulls (in two periods)

Nutrient intake	Concentrate feeding levels		*P* - value	CP levels		*P* - value	SEM[1/]	C*P[2/]
	1.0% BW	1.5% BW		CP14%	CP16%			
(0-66 day)								
GE (kJ/ $BW^{0.75}$/d)	10.40	12.61	0.0012	2,244.90	2,287.94	0.5215	35.06	0.4364
CP (g/ $BW^{0.75}$ /d)	2.37	2.75	<0.0001	11.17	11.84	0.0006	0.31	0.1429
EE (g/ $BW^{0.75}$ /d)	2.37	2.75	<0.0001	2.54	2.58	0.3588	0.05	0.4169
Ca (g/ $BW^{0.75}$ /d)	0.79	0.84	0.0025	0.81	0.83	0.5306	0.01	0.4373
P (g/ $BW^{0.75}$ /d)	0.29	0.34	<0.0001	0.31	0.32	0.1982	0.01	0.3732
CF (g/ $BW^{0.75}$ /d)	36.92	36.28	0.6080	37.22	35.98	0.0446	0.64	0.8208
NDF (g/ $BW^{0.75}$ /d)	77.89	77.96	0.7217	77.71	78.15	0.7816	1.25	0.5430
ADF (g/ $BW^{0.75}$ /d)	47.69	47.97	0.5433	47.03	48.63	0.2678	0.79	0.3782
(67-126 day)								
GE (kJ/ $BW^{0.75}$/d)	2,329.30	2,467.92	0.0055	2,378.40	2,418.81	0.6664	37.58	0.5795
CP (g/ $BW^{0.75}$ /d)	10.95	13.29	<0.0001	11.74	12.50	0.0002	0.33	0.1568
EE (g/ $BW^{0.75}$ /d)	2.51	2.89	<0.0001	2.67	2.73	0.3125	0.06	0.5240
Ca (g/ $BW^{0.75}$ /d)	0.84	0.89	0.0123	0.86	0.87	0.6901	0.01	0.5825

Appendix Table 2 (Continued)

Nutrient intake	Concentrate feeding levels		*P* - value	CP levels		*P* - value	SEM[1/]	C*P[2/]
	1.0% BW	1.5% BW		CP14%	CP16%			
P (g/ $BW^{0.75}$ /d)	0.31	0.35	<0.0001	0.33	0.33	0.1805	0.01	0.4747
CF (g/ $BW^{0.75}$ /d)	39.52	38.20	0.2777	39.63	38.08	0.0455	0.77	0.9802
NDF (g/ $BW^{0.75}$ /d)	83.28	82.09	0.7366	82.68	82.69	0.5987	1.47	0.7090
ADF (g/ $BW^{0.75}$ /d)	50.97	50.52	0.9143	50.04	51.45	0.4882	0.90	0.5306
(0-126 day)								
GE (kJ/ $BW^{0.75}$/d)	2,274.12	2,423.35	0.0013	2,317.75	2,379.73	0.2523	34.20	0.7374
CP (g/ $BW^{0.75}$ /d)	10.75	13.05	<0.0001	11.49	12.31	<0.0001	0.32	0.2579
EE (g/ $BW^{0.75}$ /d)	2.46	2.84	<0.0001	2.61	2.68	0.0799	0.05	0.7418
Ca (g/ $BW^{0.75}$ /d)	0.82	0.87	0.0030	0.84	0.86	0.2677	0.01	0.7363
P (g/ $BW^{0.75}$ /d)	0.30	0.35	<0.0001	0.32	0.33	0.3800	0.01	0.6695
CF (g/ $BW^{0.75}$ /d)	38.46	37.51	0.3735	38.53	37.44	0.0717	0.65	0.8348
NDF (g/ $BW^{0.75}$ /d)	81.10	80.61	0.9898	80.40	81.32	0.9736	1.25	0.8560

Appendix Table 2 (Continued)

Nutrient intake	Concentrate feeding levels		*P* - value	CP levels		*P* - value	SEM[1/]	C*P[2/]
	1.0% BW	1.5% BW		CP14%	CP16%			
ADF (g/ $BW^{0.75}$ /d)	49.65	49.60	0.8037	48.66	50.60	0.1567	0.79	0.6364

[1/] standard error of the mean
[2/] interaction between two factors

Appendix Table 3 Effects of supplementary concentrate feeding levels and protein levels on feed cost (in two periods)

Feed cost	Concentrate feeding levels		*P* - value	CP levels		*P* - value	SEM[1/]	C*P[2/]
	1.0% BW	1.5% BW		CP14%	CP16%			
Concentrate cost (baht)								
(0-66 day)	1,140.6	1,783.11	<0.0001	1,479.42	1,444.3	0.7378	95.95	0.5929
(67-126 day)	1,223.13	2,040.24	<0.0001	1,637.23	1,626.15	0.4309	117.48	0.7671
(0-126 day)	2,363.73	3,823.35	<0.0001	3,116.64	3,070.44	0.4997	212.92	0.6854
Grass cost (baht)								
(0-66 day)	122.823	115.881	0.0163	117.718	120.985	0.1572	1.75	0.5336
(67-126 day)	137.503	132.597	0.1668	134.076	136.023	0.5257	1.69	0.5956
(0-126 day)	260.33	248.48	0.0596	251.79	257.00	0.3182	3.34	0.5612
Total feed cost (baht)								
(0-66 day)	1,263.43	1,898.99	<0.0001	1,597.13	1,565.28	0.6084	95.59	0.6417
(67-126 day)	1,360.63	2,172.84	<0.0001	1,771.3	1,762.17	0.4029	117.09	0.8017
(0-126 day)	2,624.06	4,071.83	<0.0001	3,368.44	3,327.45	0.4381	212.14	0.728

Appendix Table 3 (Continued)

Feed cost	Concentrate feeding levels		*P* - value	CP levels		*P* - value	SEM[1/]	C*P[2/]
	1.0% BW	1.5% BW		CP14%	CP16%			
Feed cost per gain (baht/kg)								
(0-66 day)	24.31	24.91	0.8012	25.73	23.50	0.3328	0.98	0.3807
(67-126 day)	37.73	37.99	0.9046	33.58	42.13	0.0358	2.84	0.1018
(0-126 day)	28.26	30.35	0.2756	29.15	29.45	0.6733	0.89	0.8521

[1/] standard error of the mean
[2/] interaction between two factors

Appendix Table 4 Carcass yield and composition of the Kamphaeng Saen steers in 2nd experiment

Parameters	Different energy sources		*P* - value	Different CP levels		*P* - value	SEM[1/]	E*P[2/]
	cTMR	ccTMR		12%CP	14%CP			
Organs and offal weights expressed as % of slaughter weight								
WCW (%)	59.18	59.34	0.7950	58.97	59.54	0.3635	0.37	0.5738
Entrails W (%)	18.11	17.47	0.2493	17.87	17.71	0.7702	0.32	0.0806
Hide (%)	8.96	9.25	0.4684	9.03	9.18	0.7100	0.20	0.0823
Head (%)	3.11	3.10	0.9198	3.16	3.05	0.1153	0.04	0.3755
Front feet (%)	0.84	0.84	0.8657	0.82	0.86	0.2083	0.01	0.2007
Rear feet (%)	0.89	0.90	0.6981	0.88	0.91	0.3669	0.02	0.1179
Penis (%)	0.18	0.20	0.1678	0.19	0.18	0.3752	0.01	0.2426
Tail (%)	0.29	0.28	0.3789	0.28	0.29	0.3947	0.01	0.4952
Muscle attached to liver (%)	0.22	0.21	0.4329	0.23	0.21	0.0604	0.01	0.7096
Kidney (%)	0.17	0.17	0.7639	0.17	0.17	0.8408	0.01	0.035
KPH fat (%)	5.48	5.95	0.2690	6.11	5.33	0.0764	0.22	0.2099

Appendix Table 4 (Continued)

Parameters	Different energy sources		*P* - value	Different CP levels		*P* - value	SEM[1/]	E*P[2/]
	cTMR	ccTMR		12%CP	14%CP			
Carcass weight and entrails weight								
slaughtering BW (kg)	495.42	475.83	0.0323	478.42	492.83	0.1029	7.31	0.4869
WCW (kg)	292.75	282.33	0.0641	281.79	293.29	0.0434	4.04	0.7536
CCW (kg)	290.36	279.15	0.0694	278.22	291.29	0.0376	4.07	0.8071
Entrails weight (kg)	89.91	83.36	0.0555	85.85	87.42	0.6267	2.42	0.0788

[1/] standard error of the mean
[2/] interaction between two factors

CIRRICULUM VITAE

NAME : Mr. Nann Winn Soe

BIRTH DATE : August 2, 1980

BIRTH PLACE : Budalin, Myanmar

EDUCATION :

YEAR	INSTITUTE	DEGREE/DIPLOMA
2006	Univ. Vet. Sci.	B.V.Sc.

POSITION/TITLE : Deputy Supervisor

WORK PLACE : Livestock Feedstuff and Milk Products Enterprise, Ministry of Livesock and Fishery, Republic of the Union of Myanmar

SCHOLARSHIP : Thailand International Development Cooperation Agency (2011-2013)