

THESIS

RESEARCH AND DEVELOPMENT PROJECTS ON
IMPROVEMENT OF THE POTENTIAL USE OF DRIED CASSAVA
PULP AND CASSAVA LEAF MEAL IN CONCENTRATE OF
FEEDLOT CATTLE

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Six consecutive research and development projects were carried out to improve the potential use of dried cassava pulp and cassava leaf meal in concentrate of feedlot cattle. The first project was a survey study on general information of cassava pulp produced in four cassava starch factories and of cassava pulp and leaf meal used as cattle feed by farmers in the central area of Thailand. It was found that wet cassava pulp were produced approximately 0.112, 0.058, 0.096 and 0.09 million tons/year for factory No.1, 2, 3 and 4, respectively and price of wet pulp varied from 150 - 700 baht/ton while dried pulp varied from 1.4 - 4.4 baht/kg. Wet cassava pulp was used as feed supplement in feedlot cattle and mixed in form of concentrate for dairy cattle while dried cassava pulp was never used. Local feedlot and dairy producers had no idea on using of cassava leaf meal in concentrate due to the price of other protein sources was not too high. The second project was preliminary evaluation on various methods of using ensiled cassava pulp as main energy source for feedlot cattle. The animals were randomly assigned to 3 groups and received ensiled cassava pulp mixed with either leucaena leaf meal, corn stover or corn stover, leucaena leaf meal and sugarcane bagasse as sources of roughage. The results indicated that ensiled cassava pulp should not be used as the main feeding diet to the feedlot cattle due to its high moisture content which resulted in low dry matter intake and performance of the cattle. The third project aimed at replacing cassava chips in concentrate with dried cassava pulp (DCP) at a level of either 10, 20 or 30 % for feedlot cattle. The animals were randomly allocated to 4 groups and fed experimental diets *ad libitum* supplemented with 3 kg. of para grass per head daily. It was found that feedlot cattle fed experimental diets showed no significantly differences on feeding performance and carcass quality. Therefore, DCP could be included at the levels of up to 30% in concentrate without any adverse effect on productive performance. The fourth project was conducted to determine the effects of feeding DCP as a main source of energy at a higher level in concentrate on feeding performance, carcass quality and economic return of feedlot cattle. The animals received either control concentrate (CTRL), concentrate in which cassava meal was replaced by dried cassava pulp (DCP) at 50 (DCP50) or 100% (DCP100) by weight. The results indicated that feedlot cattle on CTRL showed the best feedlot performance and carcass quality as compared to the other groups. However, the difference was not statistically significant ($p>0.05$). The DCP50 had higher economic return compared to the CTRL and DCP100. The fifth project was conducted to study the effects of cassava leaf meal (CLM) in concentrate on feeding performance, carcass quality and economic return of feedlot cattle. It was found that feedlot performances of the cattle fed concentrate with either CLM or conventional protein sources were similar. Also, carcass qualities, carcass composition and some beef eating qualities of the feedlot cattle were not significant different. The final project was conducted to evaluate farmer's adoption and comments on the research projects' results after transferring technical knowledge to the farmers via training courses. The results showed that farmers accepted the concepts and had more confidence to use dried cassava pulp or leaves as feed ingredient to reduce the production cost when the price of cassava chips or other protein sources was high.

Student's signature

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RESEARCH AND DEVELOPMENT PROJECTS ON IMPROVEMENT OF THE POTENTIAL USE OF DRIED CASSAVA PULP AND CASSAVA LEAF MEAL IN CONCENTRATE OF FEEDLOT CATTLE

INTRODUCTION

The ever increasing global population as well as education level has resulted in increasing the demand not only the quantity but also the quality of foods consumed by the people as well. A higher demand of foods has continuously elevated price of the cereals which has forced the animal industry to look for the alternative cheaper feed ingredients in order to maintain the animal production cost. On the other hand, animal origin food safety is very much concerned by the modern society. Animal production needed to be more organic, minimum to no use of drugs, antibiotics or chemotherapeutics during the rearing period. A good quality feed for the animal is even more important and needed to be more concerned for successful animal production.

Cassava (*Manihot esculenta*, Crantz) is a tuber crop that widely grown in tropical and sub-tropical areas. It can be easily thrive in sandy-loam soil with low organic matters, receiving low rainfall and high temperatures. It is therefore a cash crop cultivated by small-holder farmers within the existing farming systems in many countries. Cassava is a major raw material used in many industries in Thailand. Production of cassava starch, sweeteners, MSG (Monosodium glutamate) and other amino acids, ethanol, makes a wider use of cassava. It has been reported that 40% of the total production of cassava tuber are processed to be cassava chips and pellet. Cassava chips and pellet contain high levels of energy and minimal levels of crude protein and have been used as animal feed ingredient in feed rations. Approximately 10 million tons of fresh cassava roots are used for cassava starch manufacturing from the production of about 18 million tons per year. Due to the process, around 10-15% of cassava pulp is produced (depending on its moisture content) as by-product. It is estimated that 1.0 - 1.5 million tons of wet cassava pulp or 0.2 - 0.3 million tons of dried cassava pulp produced each year while cassava leaves (approximately 2.4 million tons of fresh cassava leaves or 0.72 million tons of dried cassava leaves per year) are thrown away during the harvesting of cassava roots. High starch and moisture content in cassava pulp caused problems in the drying process and will cause spoilage later. Although the protein content in cassava leaves is around 22-25%, the farmers still reject the utilization of cassava leaves as protein supplement or feed ingredient in feed ration due to toxic content in the leaves. Many farmers have no experience in the utilization of cassava leaves and have no idea how to feed the animals especially ruminants.

Up till now, cassava pulp is dried and used in adulterating of cassava chips and pellet to make up quantity while the supreme quality is out of concern and cassava leaves are thrown away during the harvesting of the cassava roots. Many

studies have been done on the use of cassava pulp and leaves (cassava hay) in dairy cattle. Production performance of the dairy cattle has satisfied to some extent in using cassava pulp and leaves as feed ingredient and protein supplement, respectively, while fewer studies have been done in beef cattle especially the feedlot cattle.

The objective of this research project is to find out the possibility of using cassava pulp and leaves in feedlot cattle to reduced the production cost at time where the price of many feed ingredients rise up. It is estimated that 0.6 – 0.8 million heads of feedlot cattle produced each year from approximately 0.4 - 0.6 million small holder families. This research project is not only helping the farmers who raise the feedlot cattle but also to be the gate way of using by-product from cassava planting in the future. On the other hand, the research team believes that the new supplemented income of the other small farmers around the cassava planting area from drying cassava pulp, leaves or ensiled cassava leaves will be possible and could be sold directly or indirectly to the feedlot operators.

OBJECTIVES

These research projects were carried out to study current situation of cassava pulp and leaf meal produced and used in feedlot cattle in Thailand, the effect of levels and methods of using cassava pulp and leaves as feed ingredient in the concentrate on production performances, carcass quality and conformation, some beef eating quality and economic return of feedlot cattle and finally to evaluate farmers' adoption of technology on using of cassava pulp and leaf meal for feedlot cattle. These research and development projects were divided into 6 consecutive studies as follow.

1. Observation on general information of cassava pulp produced and cassava pulp and leaf meal used as cattle feed in the central part of Thailand.
2. Preliminary evaluation on various methods of using ensiled cassava pulp as main energy source for feedlot cattle.
3. Effects of replacing cassava chip with dried cassava pulp in concentrate on feeding performance, carcass quality and economic return of feedlot cattle.
4. Effects of dried cassava pulp as a main source of energy in concentrate on feeding performance, economic return, carcass composition and some beef eating qualities of feedlot cattle.
5. Effects of cassava leaf meal in concentrate on feeding performance, economic return, carcass composition and some beef eating qualities of feedlot cattle.
6. Farmers' adoption of using cassava pulp and cassava leaf meal as cattle feed.

Expectation of the benefit of this research projects

1. The results from this research will be used as the basic knowledge in utilization of cassava pulp and leaves in feedlot cattle.
2. More adoption of cassava pulp and leaves in feedlot cattle and increasing the value of cassava pulp and leaves.
3. The appropriate form and level of cassava pulp and leaves used in the feedlot ration (concentrate).
4. To reduce the production cost of feedlot cattle and increase the income to the farmers who raise feedlot cattle.
5. To reduce the problem of adulterating cassava pulp into the cassava chips and pellets in order to reach the prime quality for exporting.

6. The farmers around the cassava planting area and cassava starch factories have new additional source of income from drying cassava pulp, leaves or ensiled cassava leaves and sell directly or indirectly to the feedlot producers.

7. The results from these research works could provide the possibility for the better successful of the feedlot producers especially the small farmers.

8. More stable of cassava root price due to the better utilization of cassava root products and wastes.

LITERATURE REVIEW

1. Feedlot production in Thailand

A feedlot or feed yard is a type of Confined Animal Feeding Operation (CAFO) (also known as "factory farming") which is used for finishing livestock, notably beef cattle, prior to slaughter ([Wikipedia, 2008](#)). Each animal may be given as little space as 9m². Even though many cattle feedlots are in hot and dry parts of the country and shade and shelter are not all provided. Prior to entering a feedlot, cattle spend most of their life grazing on rangeland or on immature fields of grain such as green wheat pasture. Once cattle obtain an entry-level weight, about 650 pounds (300 kg), they are transferred to a feedlot for fattening with a specialized diet. Feedlot diets are usually very dense in food energy, to encourage the deposition of fat, or marbling, in the animal's muscles; this fat is desirable as it leads to 'juiciness' in the resulting meat. Cattle are taken to the feedlot at 12 - 14 months of age. For the domestic market they are kept there for 60-70 days. The Japanese like fat beef, so for the export market the cattle are grain fed for 120 - 150 days, possibly as long as 300 days (<http://www.animal-lib.org.au/subjects/subjects/cows--feedlots.htm>, 2/7/2008). The animal may gain an additional 400 pounds (180 kg) during its 3-4 months in the feedlot. It takes 7.45 kg. of feed to produce 1 kg. of weight gain. Once cattle are fattened up to their finished weight, the cattle are transported to a slaughterhouse (Thompson and O' Mary, 1983). Feedlots bring large numbers of animals into one area, and so accumulate huge quantities of waste. A 450 kg. steer produces 29 kg. of wet manure and urine each day, so a large feedlot with 30,000 animals produces 870,000 kg. of excrement every day (Clarke, 1993).

Yimmongkol (2002) indicated that the high quality beef production in Thailand is produced by using *Bos taurus* crossbred steer (prime and choice quality) at an average of 1 - 2 years with an initial weight of 250 - 300 kg. In case of the local quality beef production, young bulls or retired bulls and cows are use. Feedlot cattle are raised in feedlots and fed ad libitum with roughage and concentrate at a proper ratio or TMR until the feedlot cattle reached the final weight of 500 - 600 kg. at an average age not exceeding more than 3 years old. Slaughtering and cutting (retail cut) is done under slaughter house and cutting room standards. Prime and choice quality beef have to chill for 7 - 14 days or more before cutting and freezing while it is unnecessary in local quality. The quality of beef depends on tenderness, marbling, juiciness and aging. It is believed that 0.6 - 0.8 million heads of feedlot cattle are produced each year from approximate 0.4 - 0.6 million families of the small holders (Yimmongkol, 2002; Ungkulo, 2003).

Feedlot production in Thailand can be divided into 3 systems depends on the beef quality needed by the consumers and market (Yimmongkol, 2002; KU. KBPC, 2008 and Sretthakul and Opaspattanakij, 2005).

1.1. Local Quality (Koman I., Commercial, Utility and Cutter Quality)

The local quality beef is usually produced from retired bull and cow or live cattle imported from neighbor countries (> 90% from Myanmar) and fed in feedlot for 2 - 3 months with concentrate and roughage or total mixed ration. Thailand produces 62.4 million kg. of this quality per year. and share 40% of beef market or produces from 0.74 million heads of feedlot cattle. The local quality feedlot cattle are fed for 2 - 3 months and have final weight of 400 - 500 kg. Slaughtering is done at the local slaughterhouse with no standards and sent to the local markets immediately. Price of this quality is range from 44 - 50 baht/kg. of body weight or 75 - 80 baht/kg. of carcass weight. The central part of Thailand is the center of production especially Nakhon Pathom, Ratchaburi, Phetchaburi, Suphan Buri, Kanchanaburi, Pathumthani, Nakhon Sawan, Prachuab Khiri Khan, Chon Buri and Rayoung.

1.2. Standard Quality (Koman II. or Select and Standard Quality)

The standard quality is usually produced from young bulls (not castrated), mostly is crossbred Brahman or any crossbred young bull (at average age of 2 - 3 years) and fed in feedlot with concentrate and roughage or total mixed ration for 4-6 months. The final weight is range from 450 - 550 kg. with carcass weight of 230 - 280 kg. The quality of this beef is fit for the needs of fresh markets (wet market) in Bangkok and also supermarket and discount store. Slaughtering is done under the local slaughterhouse standards and sent to the local markets immediately. Thailand produces this quality at 92.17 million kg./year and shares of 58.5% of beef with markets or produces from 0.63 million heads of feedlot cattle.

1.3. Prime and Choice Quality

Prime and choice qualities are usually produced from *Bos taurus* crossbred steer or Kamphaeng Saen steer at an average of 1.5 - 2 years with an initial weight of 250 - 300 kg. and fed in feedlot for 8-10 months until the final weight is 550 - 600 kg. and average age are not exceed more than 3 years. Slaughtering and cutting (retail cut) is done under the slaughterhouse and dressing room standards; food safety and traceability standards are also required. Carcass weight ranges from 300 - 320 kg. or 58 - 62% 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 at 1.79 million kg./year and share 1% of beef with markets or produces from 0.01 million heads of feedlot cattle.

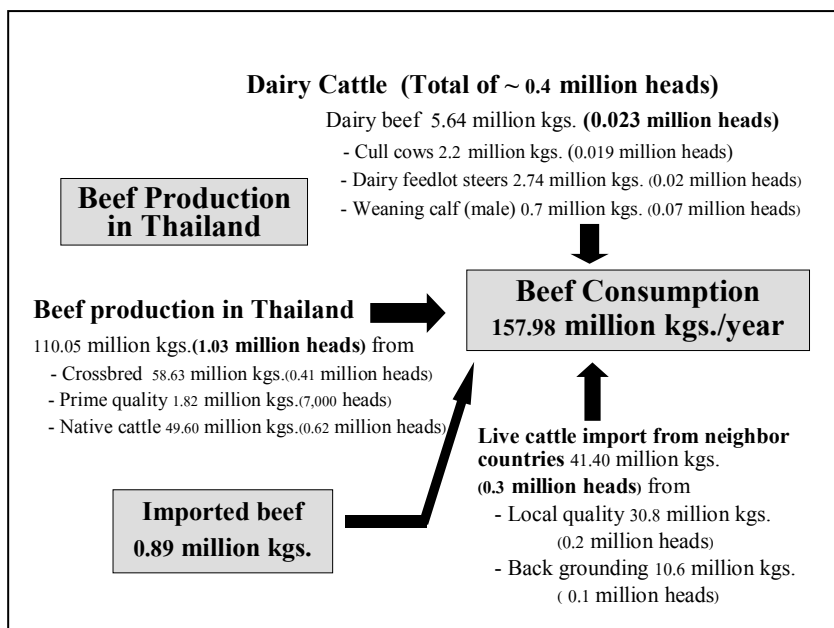


Figure 2 Beef production in Thailand

Source: Adapted from OAE (2005)

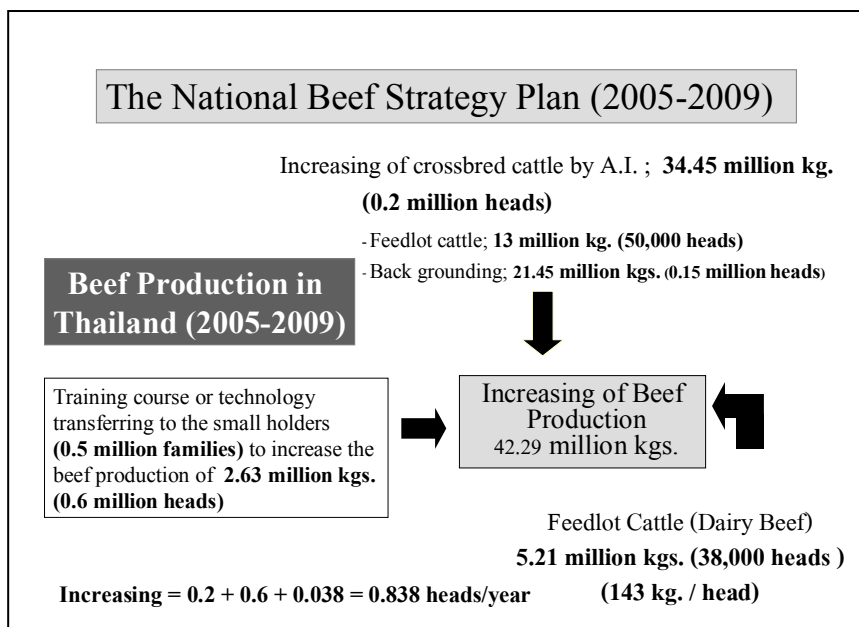


Figure 3 The strategy plan of beef production in Thailand

Source: Adapted from OAE (2005)

Table 1 Production cost of feedlot cattle

Items	Unit	Crossbred Brahman			Retired bull & Cow	
		Case 1	Case 2	Case 3	Case 1	Case 2
Initial weight	kg.	200.00	200.00	250.00	350.00	350.00
Price	baht/kg.	43.00	43.00	45.00	45.00	45.00
Final weight	kg.	450.00	450.00	450.00	450.00	450.00
Feeding period	days	278.00	250.00	200.00	111.00	100.00
ADG.	kg./day	0.90	1.00	1.00	0.90	1.00
Intake of concentrate	kg./h./d.	5.50	5.50	6.50	7.00	7.00
Price of concentrate	baht/kg.	4.20	4.20	4.20	4.20	4.20
Intake of roughage	kg./h./d.	16.00	16.00	16.00	16.00	16.00
Price of roughage	baht/kg.	0.50	0.50	0.50	0.50	0.50
Labor cost	baht/h./d.	3.00	3.00	3.00	3.00	3.00
Cost of health management	baht/h.	200.00	200.00	200.00	200.00	200.00
Depreciation of infrastructure & miscellaneous	baht/h./d.	1.00	1.00	1.10	1.10	1.10
Cost of transportation	baht/h.	500.00	500.00	500.00	500.00	500.00
Interest on loan	%	11.50	11.50	10.00	10.00	11.50
Price of dried manure	baht/kg.	1.00	1.00	1.00	1.00	1.00
Dried manure	kg./h./d.	4.00	4.00	4.00	4.00	4.00
Cost of feedlot cattle	baht	8,600	8,600	11,250	15,750	15,750
Production cost of concentrate	baht	6,421	5,775	5,460	3,263	2,940
Production of roughage	baht	2,224	2,000	1,600	888	800
Total Cost of health management	baht	200.00	200.00	200.00	200.00	200.00
Total Cost of transportation	baht	500.00	500.00	500.00	500.00	500.00
Total Cost of Depreciation & miscellaneous	baht	278.00	250.00	220.00	122.00	110.00
Interest	baht	1,052	938.28	825.00	507.00	497.00
Total labor cost	baht	834.00	750.00	600.00	333.00	300.00
Total production cost	baht	19,039	18,095	20,655	21,565	21,094
Production cost	baht /kg.	39.84	38.00	45.92	47.92	46.87

Source: DLD (2004)

Table 2 Production cost of feedlot cattle (Charolais and Thai Native)

Items	Unit	Charolais crossbred	Native
Initial weight	kg.	250.00	120.00
Price	baht/kg.	55.00	40.00
Final weight	kg.	500.00	300.00
Feeding period	days	210.00	360.00
ADG.	kg./day	1.20	0.50
Intake of concentrate	kg./h./d.	7.50	2.00
Price of concentrate	baht/kg.	4.20	4.20
Intake of roughage	kg./h./d.	16.00	12.00
Price of roughage	baht/kg.	0.50	0.50
Labor cost	baht/h./.	3.00	3.00
Cost of health management	baht/h.	200.00	100.00
Depreciation of infrastructure & miscellaneous	baht/h./d.	1.00	1.00
Cost of transportation	baht/h.	500.00	200.00
Interest on loan	%	11.50	11.50
Price of dried manure	baht/kg.	1.00	1.00
Dried manure	kg./h./d.	4.00	3.00
Cost of feedlot cattle	baht	13,750.00	4,800.00
Production cost of concentrate	baht	6,615.00	2,520.00
Production of roughage	baht	1,680.00	2,160.00
Total Cost of health management	baht	200.00	100.00
Total Cost of transportation	baht	500.00	200.00
Total Cost of Depreciation & miscellaneous	baht	231.00	360.00
Interest	baht	1,085.00	859.00
Total labor cost	baht	630.00	1,080.00
Total production cost	baht	24,751.00	12,079.00
Production cost	baht/kg.	49.50	36.70

Source: DLD (2004)

2. Utilization of cassava by-products in feedlot cattle

Cassava (*Manihot esculenta*, Crantz) is a tuber crop that grows widely in tropical and sub-tropical areas. It can easily thrive in sandy-loam soil with low organic matter, receiving low rainfall and high temperatures. It is there for a cash crop cultivated by small-holder farmers within the exiting farming systems in many countries (Wanapat, 1999). Thailand is a major producer of cassava, with an annual yield of 20 - 25 million tons, accounted for about 10 percent of the global production. Approximately 40 percent of the cassava produced in Thailand is processed into cassava starch, for which the domestic demand is as high as 1.3 - 1.7 million tons per year (TTSA: Thai Tapioca Starch Association, 2008a).

Table 3 The statistical records of cassava growing in Thailand : Area, production, yield, farm price and farm value, 1998-2007

Year	Planted area (1,000 rai)	Harvested area (1,000 rai)	Production (1,000tons)	Yield/rai kg.	Farm price bath/kg.	Farm value (Million bath)
1998	6,694	6,527	15,591	2,388	1.26	19,644
1999	7,200	6,659	16,607	2,479	0.91	15,021
2000	7,406	7,069	19,064	2,697	0.63	12,010
2001	6,919	6,558	19,396	2,805	0.69	12,693
2002	6,224	6,176	16,868	2,731	1.05	17,712
2003	6,435	6,386	19,718	3,087	0.93	18,337
2004	6,757	6,609	21,440	3,244	0.80	17,152
2005	6,524	6,162	16,938	2,749	1.33	22,528
2006	6,933	6,693	22,584	3,375	1.29	29,134
2007	7,479	7,201	26,411	3,668	1.12	29,581

Source: Office of Agricultural Economics (2006)

The development technology for cassava starch processing can be divided into three phases. The first phase is the production of cassava flour. It is processed from fresh roots using simple techniques like sedimentation. The wet flour is dried by baking it on a hot surface. The second phase is the production of cassava starch using more sophisticated techniques based on centrifugal forces for starch separation and dewatering. The resulting moist starch is dried in a flash drier. Currently, there are 48 factories registered as members of the Thai Tapioca Starch Industries Trade Association (TTSA). All of these factories use the centrifugal technique and flash drier in their starch processing plants, the starch obtained from this process is highly pure and regarded as top-quality starch. The third phase of technology development involves environmental concerns and safety issues. Clean technology or Zero Discharge System has been implemented; this includes issues like energy and waste management (e.g. biogas production). The principles of GMP (Good Manufacturing Practices) and HACCP (Hazard Analysis and Critical Control Points) have also been

incorporated. In addition, the manufacturing process has been developed into ISO 9000 standards. All cassava starch factories in Thailand use the processing technology of the second phase and are currently in the transitional stage to develop into the third phase. Based on the production capacity, manufacturing plants can be divided into

- a) Large-sized factories with the production capacity over 200 tons per day.
- b) Medium-sized factories with the production capacity of 100 - 200 tons per day.
- c) Small-sized factories with the production capacity of 100 tons or less per day.

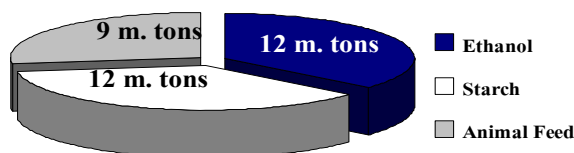


Figure 4 Utilization of cassava root in Thailand

Source: Adapted from Office of Agricultural Economics (2006)
Sriroth and Piyajomkwan (2007)

2.1. Cassava Starch Manufacturing Process (Thai Tapioca Starch Association, 2008a)

2.1.1. Raw material preparation

As soon as cassava roots arrive at a processing plant, the factory's representative randomly takes like samples of the roots to determine their starch content. This is necessary since the purchase price is set on the basis of starch content. The roots are first piled up on the ground, then put into a hopper, and transferred to a conveying belt where the woody ends of the roots are cut off by workers. The roots are then passed to a sieve to separate loose peels, sand and any adhering dirt.

The roots are washed in a root washer. The number or length of the washer depends on the production efficiency of a factory. Washing water from a washer containing some loose peels is passed to a rotary screen, a perforate cylindrical tank with a spiral part driving the retained loose peel to an outlet. Water passing through the screen then enters the wastewater treatment system. One of the most important factors in the development of starch production is the management of raw material. The quality of cassava roots has a significant effect on the quality of the final product.

As soon as the roots are harvested, they must be immediately transported to a factory. Factories need to improve the storage conditions such as providing storage areas with a roof and an improve inventory system for cassava roots, like using a first-in, first-out system. The detailed information about the roots such as varieties, the age of harvested roots, starch content, and planting location needs to be recorded. It has been clearly shown that these factors greatly affect the quality of the starch product.

2.1.2. Rasping of cassava roots

Washed roots are transported via a conveyor belt to a root chopper. Inside this machine, the cassava roots are chopped into smaller pieces with large cutting blades. The chopped roots are then taken to a rasper, a drum aligned horizontally on its surface, rotating at about 1,000 rpm. The drum is approximately 77.5 cm. in diameter, equipped with 144 blades, which are 30 cm. in length. During rasping, water is used to facilitate the process. The resulting suspension (rasped fresh pulp) consists of starch, water, fiber, and other impurities.

In general, a small rasper drum, with a high number of blades per surface area, is used with a rather low speed to avoid such a fine pulp that may create difficulty in starch extraction, which could lead to low production efficiency. Recent development has led to a larger rasping drum with fewer blades (about 80 - 83) able to run at a higher speed (about 1,450 - 2,000 rpm), which results in higher production efficiency.

2.1.3. Starch extraction

The extraction of starch starts by pumping the rasped fresh pulp into a decanter, a cylinder with conical ends separates the water containing protein and fat from the extracted using centrifugal force. The decanter rotates at a speed of 3,000 rpm. It is usually the first step after the rasper. However, the pulp is sometimes fed directly into an extractor since decanters are not installed in all factories.

The extractor, used to separate starch slurry from the fiber and pulp, is a cone-shaped perforated stainless steel basket constantly spinning at 600 - 800 rpm. The starch granules are small enough to pass through the pores of the perforated basket into an outer tank. Larger pulp particles, retained inside the basket, are discharged at the upper outlet. Water is constantly applied to the machine to facilitate starch extraction. There are two types of extractors: a coarse extractor with a perforated basket of 35 - 40 mesh and a fine extractor with a filter cloth of 100 - 120 mesh or 140 - 200 mesh placed on the perforated basket. An aqueous solution of sulfur dioxide is used in the fine extractor to prevent the formation of slimy film that could clog the filter cloth. This also prevents loss of starch by microorganisms and helps in bleaching of the starch. The use of sulfur dioxide solution is very important to the extraction process. Different amounts of sulfur dioxide used resulted in different qualities of starch. The starch slurry is passed to the coarse extractor first to separate a

coarse pulp, and then passed to a fine extractor to separate fine pulp. The coarse and fine pulp are then passed to a pulp extractor and pressed into dry pulp with a screw press. Extractors are generally used in sets arranged in two lines with a trough between them to receive the discharged from the extractors. One factory has 4 - 6 sets, with 6 - 12 machines per set.

Recently, new technology for starch extraction and pulp pressing has been developed; a vibrating screener is used instead of a fine extractor. It is a rectangular screen of 150 - 250 mesh that vibrates constantly. This is more efficient than a fine extractor. In some factories, belt presses have been used in place of screw presses. This is a belt moving on rollers to squeeze water out of the wet pulp. A blade is located at the end of the belt to scrapes the pulp off. The resulting pulp contains lower moisture content than that obtained from a screw press. The belt press supports the processing plant with large raspers operating at higher speeds.

The starch slurry from fine extractors is purified and concentrated in a separator. Generally, a 2-phase nozzle type separation machine is used. This method utilizes centrifugal force created by rotating the machine at about 3,000 rpm. The liquid that enters the machine is separated into two phases: concentrated starch slurry and clear water with impurities (mostly used to wash the roots). Factories usually use two sets of separators. The final starch slurry obtained is held and entered the dewatering process. Many factories have installed three sets of separators so that starch slurry leaves the separators with a constantly high concentration.

To improve the separation process, a 3-phase nozzle type separation machine has been developed. This uses the same principles as the 2-phase machine, but the liquid is separated into three phases: the heavy phase, the medium phase, and the light phase. The medium phase liquid contains small starch granules and fine pulp. It can be reused in the process but fine pulp has to be removed first. The light-phase liquid has less impurity and can be reused. The 3-phase machine uses a less water and reduces the number of steps in separating the starch. In the use of a hydrocyclone to facilitate the separation of impurities and chemicals from starch slurry and the installation of a densitometer to measure the concentration of starch slurry are also necessary to obtain starch slurry and starch product with consistent quality.

The starch slurry from the separators is pumped to a dewatering centrifuge. With filter cloth placed inside it, rotates at about 1,000 rpm to remove water from the starch slurry. Some factories use high quality filter cloth to prevent loss of starch granules through the filter, The resulting starch cake, scraped off the machine by workers, has a moisture content of 35 - 40 %, It starch cake is then taken to the drying unit. Presently, larger and automatic dewatering centrifuges are being used. Other dewatering systems have been tested. It has been shown that high pressure filtration greatly reduced moisture content of the starch cake. The resulting filtrate also has low solid content.

2.1.4. Drying process

Cassava starch is dried using a pneumatic conveying dryer; a burner is generally used to generate heat. There are two types of burners in use today: hot air burners and thermo-oil boilers. Air, heated to 170 to 200 °C, is used to dry the starch cake in a flash dryer. The starch is transferred to a drying cyclone and then a cooling cyclone. The dried starch is then sifted to assure uniform particles. The sifted starch is normally packaged in small bags of 20, 30 and 50 kilograms. Jumbo bags holding 500 and 1,000 kilograms are also used.

The direction for development of drying technologies is to reduce energy costs associated with drying the starch. This includes the production of biogas from the wastewater, which is very suitable because biogas can be used to generate energy in the production process (accounted for about 75% of required energy). The number of years required for a return on investment can be estimated.

2.1.5. Packaging and storage

Since dried starch contains low moisture content of 9 - 11% and low density, a lot of dust is generated during packaging. If the storage of starch is available prior to packaging, its moisture content will come close to equilibrium with the atmosphere and there will be less dust generated during packaging. The packages bags are placed on pallets, with stacks of more than four or five meters being avoided. The packaged starch is stored and distributed based on a first-in, first-out system.

There are many factors that significantly affect the quality and physicochemical properties of the starch during storage including temperature, relative humidity, and storage time. When stored in areas of high relative humidity, the starch absorbs greater amount of moisture. As a result, the bulk swelling power of the starch decreases. Conversely, starch stored in areas of low relative humidity has lower moisture content. As a result, it has a greater water uptake and a higher bulk swelling power. Besides, storage in high relative humidity areas for a long period of time causes the starch to deteriorate due to microorganisms and biochemical reactions, swelling power and percentage of solubility of cassava starch decreased as the degree of microbial contamination increased, the amount of sulfur dioxide also greatly affects the quality of cassava starch during storage. It has been shown that viscosity of starch with high amount of sulfur dioxide decreases faster than that of starch with lower amount of sulfur dioxide.



1. Raw material preparation and then put into a hopper and transferred to a conveying belt.



2. The woody ends of the roots are cut off by workers and then passed to a sieve to separate loose peels, sand and any adhering dirt.



3. The roots are washed in a root washer and washed roots are transported via conveyor belt to a root chopper. The washed roots (inner part of the peel) represent about 8.5% of the weight of the whole root.

Figure 6 (continued)



4. Rasing of cassava root. During rasing, water is used to facilitate the process. The resulting suspension (rasped fresh pulp) consists of starch, water, fiber and other impurities.



5. Starch extraction

Figure 6 (continued)



6. Drying process



7. Packaging and storage



8. Cassava pulp as waste product



Figure 6 Cassava starch manufacturing process

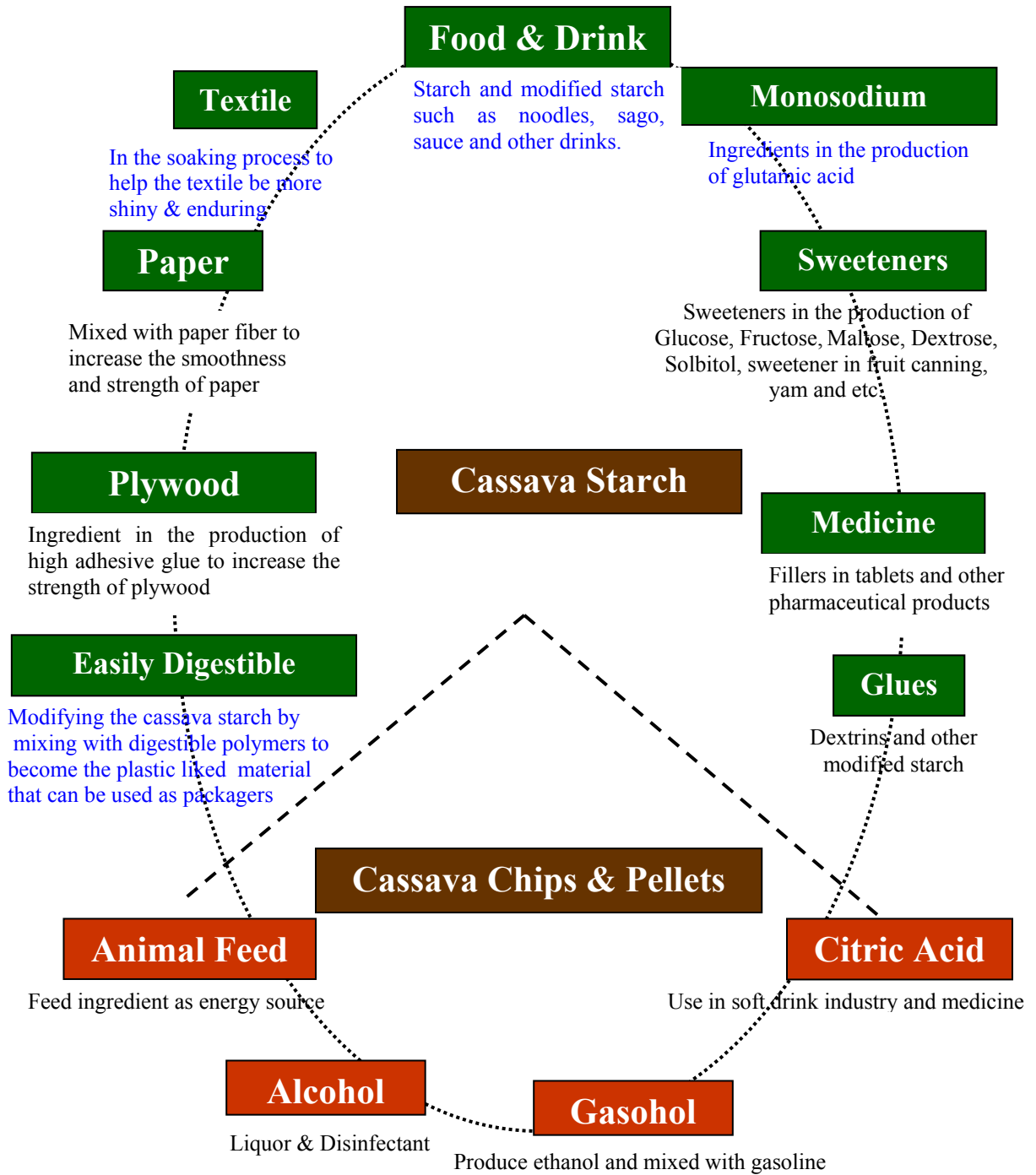


Figure 7 Utilization of cassava roots

Source: Adapted from Thai Tapioca Starch Association (2007)

2.2. Commercial Products from Cassava Starch

Thailand is a major producer of cassava. Cassava roots from farms are normally transported to processing factories for production of cassava pellets and chips which are used as animal feed or exported. Some factories extract starch from the roots or dried chips. Industrial processing of cassava starch has been a dominant productive sector which consumes a sizable portion of the cassava roots from the farms. It takes 2.3 - 2.5 tons of fresh roots to yield 1 ton of pellets or chips. However, 4 - 4.4 tons of the fresh roots will be needed to yield 1 ton of starch. Cassava starch has been widely used and converted into many industrial products. By category, the starch usage may separate into 4 groups as follow (Table 4) (Chulavatnatol, 2001).

Table 4 Estimation of cassava starch consumption in various industries of Thailand

<u>Direct use</u>	%	<u>Hydrolytic products</u>	%
Paper industry	11.49	Glucose/Fructose	11.97
Plywood industry	2.14	Sorbitol	1.55
Textile industry	1.86		
Glue	1.19	<u>Fermentation</u>	
Food	11.87	MSG/lysine	12.70
Sago	3.58		
		<u>Other use</u>	
		Other	9.49
<u>Modified starch</u>			
Chemical	25.41		
Physical	7.37		

Source: Adapted from Chulavatnatol (2001)

2.2.1. Direct use of starch

Starch is vital as a smoothening agent to the industrial production of paper and the sizing of treads in the textile industry. In plywood manufacturing, starch is used as glue between the sheets. Glue gel and liquid glue made from starch are utilized in the paper box industry and in offices. Starch is also used as thickeners in the soup and baby food production. Household use of starch in cooking and making of many traditional sweets is another major use of cassava starch domestically.

2.2.2. Modified starch

Because of certain quality requirement in special industrial applications, starch may be modified chemically. Derivatization and chemical cross-linking lead to change in physical and chemical properties of starch and hence its

applications are extended. One known application is the use of modified starch in the manufacturing of pharmaceutical caplets. Another industrial use of modified starch is in the lubrication of oil drilling.

2.2.3. Hydrolytic products

Enzymatic hydrolysis of starch by glucoamylase yields free glucose which may be further processed into intravenous glucose or food-grade glucose. Chemical hydrolysis may also be employed to produce free glucose. Further conversion of free glucose into fructose will increase the sweetness and may be used as high fructose syrup. Another conversion product is sorbitol which is a sweetener.

2.2.4. Fermentation products

Microbial fermentation of starch occurs naturally during the delayed starch extraction or during starch storage under high-moisture conditions. However, industrial production of monosodium glutamate, MSG or a sweetener, from starch or cassava roots is a growing industry. In this case, cassava has replaced molasses as the raw material. Another fermentation product from starch is lysine which is an essential amino acid supplement used in animal feed.

2.2.5. Food and pharmaceutical sector (ROHREX[®], 2008)

Cassava starch is extremely important in both the food and non-food industries. The food and pharmaceutical sector are large consumers of cassava starch. Both modified and unmodified starch and glucose are used extensively.

Uses include:

- a. Fillers in tablets and other pharmaceutical products
- b. Syrup concentrate in soft drinks and canned foods
- c. Binding agent in processed foods
- d. Bakery and confectionary
- e. Thickeners in soups, baby food
- f. Sweeteners in the production of glucose, maltose, fructose and MSG

2.2.6. None-food sector (ROHREX[®], 2008)

In the none-food sector cassava starch is used in the production of adhesives, corrugated cardboard, paper, textiles, building materials, laundry etc.

2.3. Animal Feed Ingredients from Cassava Roots

2.3.1. Cassava chips

This is the most common form in which dried cassava roots are marketed and most exporting countries produce them. The chips are dried, irregular slices of roots which vary in size but should not exceed 5 cm in length, so that they can be stored in silos. They are produced extensively in Thailand, Malaysia, Indonesia and some parts of Africa. The present method of processing chips is very simple, consisting in mechanically slicing the cassava roots and then sun drying the slices until their moisture content is only 14%: dry chips can be stored longer and are cheaper to transport. The recovery rate of chips from roots is about 20-40%. When the roots are not sorted, peeled and washed, the chips are usually brown in color and have a high content of fiber, sand and foreign objects as well as hydrocyanic acid. Trimming, peeling and washing the roots in a similar manner as the processing of cassava flour is recommended in order to produce white chips of superior quality. The roots are shredded in a special machine, which is usually made locally. The machine consists of a rotating notched cutting disk or knife blades mounted on a wooden frame equipped with a hopper. The cassava roots are cut into thin slices and pieces as they pass through the machine. A chipping-machine can do in one hour and the work which used to take three days by hand. (International Starch Institute. 1999; Kanto and Juttupornpong, 2007)

Drying: sun drying is used mostly where the sliced roots are spread out on drying areas, or concrete floors of various dimensions. The concentration of chips during drying should not exceed 10-15 kg/m², the required drying area space being about 250 m² for each ton per day of dried roots produced. To produce good quality chips the roots must be sliced and dried as quickly as possible after harvest. The chips should be turned periodically in the drying period, usually two or three sunny days, until the moisture content reaches 13 - 15%. The chips are considered dry when they are easily broken but too hard to be crumbled by hand. The thickness of the slices also has an effect on the quality of chips. Thick slices may appear dry on the surface when their internal moisture content is still high. When rain threatens during the drying process, the chips are collected by hand or by a tractor into piles under a small roof. Interrupted sun drying affects the quality of the finished chips and pellets. When the semidried chips are wet again by rain, they become soggy and upon completion of drying lose their firm texture. In rainy regions, where continuous sun drying is difficult, some form of artificial heat drying is required.

2.3.2. Broken roots

Similar to chips in appearance, but generally thicker and longer, often 12-15 cm. long broken roots can jam the mechanism of handling equipment.

2.3.3. Pellets

The pellets are obtained from dried and broken roots by grinding then into a cylindrical shape and then hardening. The cylinders are about 2 - 3 cm long and about 0.4 - 0.8 cm in diameter and are uniform in appearance and texture. The production of pelleted chips has recently been increasing as they meet a ready demand on the European markets. They have the following advantages over chips: quality is more uniform; they occupy 25 - 30% less space than chips, thus reducing the cost of transport and storage; handling charges for loading and unloading are also cheaper; they usually reach their destination sound and undamaged, while a great part of a cargo of sliced chips is damaged in long-distance shipment because of sweating and heating. Pellets are produced by feeding dried chips into the pelleting machine, after which they are screened and exported in bulk. The powdered chips which fall down during pelleting are re-pressed into pellets and the process is repeated. There is usually about 2 - 3 % loss of weight during the process.

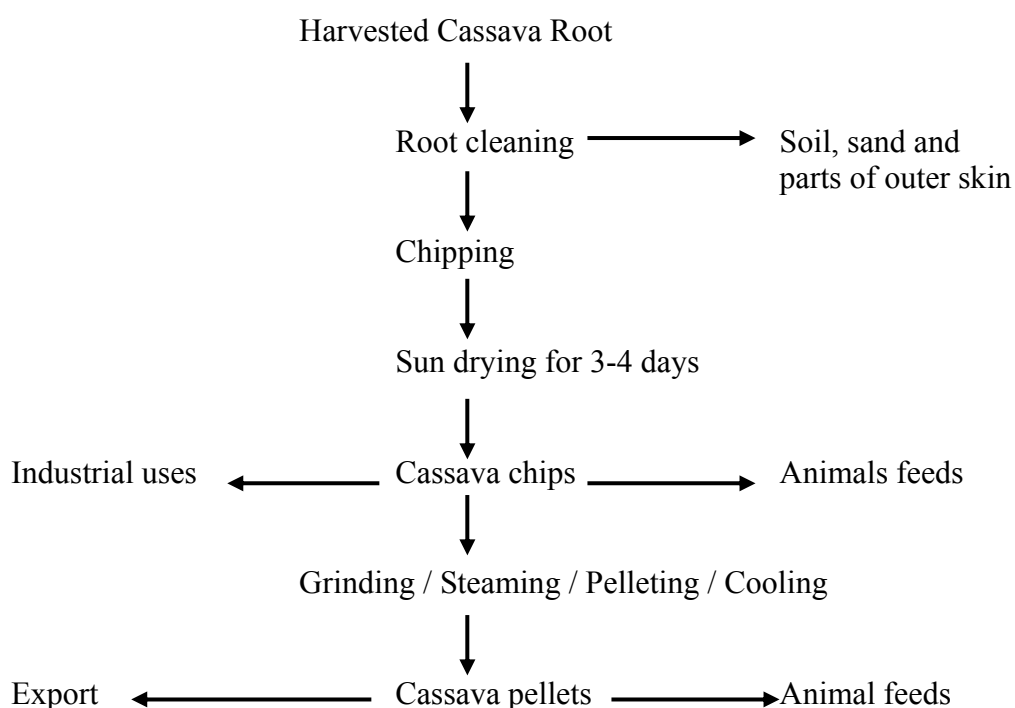


Figure 8 Schematic production of prime quality cassava chips and pellets

Source: Kanto and Juttupornpong (2007)

2.4. Utilization of Cassava Pulp in Animal Nutrition

2.4.1. Cassava pulp

During the processing of cassava starch, the residual pulp which is separated from the starch in the screening process is used as an animal feed. It is usually utilized wet drip-dry with 12 - 13% dry matter in the neighborhoods of the processing factory, or sun dried before it is sold. With efficient extraction the starch content is quite low and this pulp is utilized by ruminant only (International Starch Institute, 1999). Sriroth(1997) reported that approximately 10 million tons of fresh cassava roots are used for cassava starch manufacturing from the production of about 18 million tons per year . Due to the process, around 10-15 % of cassava pulp is produced (depending on its moisture content) as by-product. High starch and moisture content in cassava pulp causes problems in the drying process and will cause spoilage later. It is estimated that 1.0 - 1.5 million tons of wet cassava pulp or 0.2 - 0.3 million tons of dried cassava pulp are produced each year (Sriroth, 1997; Sriroth and Piyajomkwan, 2003a). The pulp is high in fermentable carbohydrates and moisture content and low in fiber and nitrogenous compounds. Due to its rich organic nature, this residue in cassava pulp can be an ideal substrate for micro organisms to grow and produce different products. It can thus be a nuisance to the environment when not well managed. The environmental pollution can, however, be managed if the pulp can be incorporated into livestock diets to be converted into high quality animal products for human consumption.

2.4.2. Nutrition value of cassava pulp

The pulp is the solid waste produced as a consequence of starch production and contains about 50 - 60% starch on dry matter basis (Sriroth *et al.*, 2000). Nitipot and Sommart (2003) collected the cassava starch industry by- products; energy source feed stuffs and roughage to determine chemical compositions and evaluated nutritive value for ruminant using in vitro gas production technique. This experiment suggested that cassava starch industry by- products had high potential to be used as novel energy feed source for ruminant. Srinorakutara *et al.* (2006) reported the chemical composition of cassava waste as been shown in Table 5 and by the others in Table 6 and 7

Jintanavanich and Juttupornpong (2008) reported that ensiled cassava pulp has up to 10^6 - 10^7 colonies/g. of lactic acid bacteria while the other feed ingredients have only 10^2 - 10^3 colonies/g. Mixing of cassava pulp with other roughage, especially cassava leaves can reduce the time of fermentation from 21 days to 10 - 14 days and HCN content in ensiled cassava leaves decline which has no effect to the animal.

Table 5 The chemical compositions of cassava waste

Composition	Cassava waste		% (w/w)	
	Sample1	Sample2	Sample3	Average
Moisture	78.16	79.50	82.74	80.13
Protein	1.82	2.03	2.31	2.05
Fat	0.09	0.20	0.16	0.15
Ash	1.61	2.38	2.05	2.01
Fiber	10.61	14.35	14.56	13.17
Starch	69.90	61.84	64.36	65.37

Note: Cyanide content in cassava waste = 154 mg/kg. dry weight and cyanide content after acid hydrolysis = 4.54 mg/kg. dry weight

Source: Srinorakutara *et al.* (2006)

Table 6 Proximate composition of feed ingredients (%)

Feed ingredient	Moisture	Dry Matter	Mineral Ash	Ether Extract	Crude Protein	Crude Fiber
<i>Stylosanthes guianensis</i>	10.4	89.7	11.0	2.33	12.6	26.5
Copra cake	10.7	89.3	10.2	4.77	23.6	11.9
Cassava peel *	11.1	88.9	6.17	0.78	5.29	9.87
Cassava pulp*	13.9	86.1	3.73	1.32	2.47	20.4

* Sun dried

Source: Baiden *et al.* (2007)

Sommart and Bunnakit (2004) have studied the use of cassava and cassava starch industry by-products in 18 crossbred yearling beef cattle (Brahman; Charolais-Brahman). The animals were offered treatment diets containing 50% of 1) cassava chip 2) cassava pulp 3) cassava peel fed at 1.5% BW with rice straw ad-libitum. Based on this experiment, although, total feed intake decreased (3.69, 3.74, 3.47 kgDM/d; $P > 0.05$) with cassava peel inclusion, but dietary treatment did not influence weight gained (0.86, 0.69, 0.84 kg/d; $P > 0.05$). The results revealed that diet containing up to 50% of cassava industry by-product as an energy source performed as well as a cassava chip diet.

Baiden *et al.* (2007) reviewed that cassava pulp, a by product from the starch industry, was evaluated as a substitute for cassava peels in diets for sheep and goats.

They reported that the pulp inclusion levels of 15% and 30% in the diet had no significant effect ($P>0.05$) on feed intake, digestibility, growth rate, feed conversion ratio and carcass weight of the West African dwarf sheep and goats.

Napasirth *et al.* (2005) studied the utilization of energy feed sources and cassava starch industry by-products in beef cattle. The study was conducted to determine the nutritive value by the in-vitro gas production technique. It was found that the rate of gas production was significantly different amongst treatments (cassava chip 0.034, corn meal 0.023, cassava peel 0.029 and cassava pulp 0.026%/hr, $p<0.01$). In vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD) at 12 hr post incubation was not a significant difference ($p>0.05$), but IVDMD and IVOMD at 24 hr post incubation was significantly different among treatments (IVDMD of cassava chip 50.20, corn meal 37.25, cassava peel 42.50 and cassava pulp 42.74%, and IVOMD 52.25, 38.80, 44.45 and 44.20% respectively; $p<0.01$). In experiment II, a study was conducted with four 1.5 year-old crossbred Brahman cattle with an average initial body weight of 160.4 ± 9.3 kg according to 4x4 Latin square design. The animals were randomly assigned to receive one of 4 dietary treatments (cassava chip, corn meal, cassava peel and cassava pulp, 50% of each in concentrate) and fed an ad-libitum of rice straw as a roughage source. It was shown that voluntary feed intake of dry matter and metabolic weight of the animals offered rations containing cassava pulp was higher than the rations containing cassava chips ($p<0.05$). However, nutrients digestibility, ruminal fermentation end-products, blood metabolites, rate of passage, and average daily gain were not significantly different ($p>0.05$). It is, therefore, concluded that the rate of gas production differed between energy feed sources. Cassava starch industry by-product can be fed as energy feed source in beef cattle.

Nitipot *et al.* (2004) have conducted the experiment to determine the effect of the dietary treatment where cassava chip was replaced by cassava pulp 0, 50 and 100% in the concentrate at 2% BW. Eighteen Holstein crossbred (87.5% HF) heifers were arranged into RCBD and were fed an ad-libitum of rice straw as roughage. The result show that roughage and total feed intake, eating behavior, fiber digestibility, rumen fermentation end-products, blood metabolize and weight gain had no significant differences ($P>0.05$), but fiber digestibility was lowest ($P<0.05$) with 100% replacement. In the second experiment, in-vitro gas production technique, there were alternative five treatments of replacing cassava chips by cassava pulp in the total mixed rations (TMR); 0, 25, 50, 75 and 100% with rice straw as roughage source. The experiment was arranged into the randomized complete block design (RCBD) with 18 replications. The kinetic and gas volume production, in vitro dry organic matter digestibility and total volatile fatty acids were not significantly different ($P>0.05$).

Skunmun *et al.* (2005) reported on the supplementation of ensiled cassava pulp and leucaena leaves to improve production performances and cost of on-farm beef production. Two beef farms were purposively selected to study, feed supplementation of 10 kg ensiled cassava pulp and 1-kg dried leucaena leaves per

animal unit were used in one farm (A) while none in the other farm (B). Production performances and cost were recorded. The results from the 6-month experiment showed that the percentage difference in total mass of the herds was 54% higher in Farm A than in Farm B, but the added herd value was 25% lower due to breed differences. On the basis of 100-kg body weight gain of the herd, Farm A had 67% lower total cost of production and 88% lower feed cost than Farm B. The findings indicated that supplementation of ensiled cassava pulp and leucaena leaves improved production performances and lowered the cost of on-farm beef production.

Table 7 Chemical composition and energy values of dried cassava pulp

Item (Chemical Composition, %)	Cassava pulp1 ^{1/}	Cassava pulp1 ^{2/}	Cassava pulp1 ^{3/}	Cassava pulp1 ^{4/}	Cassava pulp1 ^{5/}
DM	92.6±0.06	89.40	90	nd	86.1
CP	2.6±0.06	1.62	1.77	2.05	2.47
EE	0.2±0.04	0.13	nd	0.15	1.32
Ash	3.8±0.01	4.42	nd	2.01	3.73
CF	6.6±0.04	11.74	16.1	13.17	20.4
Ca	nd	0.79	0.46	nd	nd
P	nd	0.03	0.02	nd	nd
NDF	37.6±0.18	59.04	nd	nd	nd
ADF	9.8±0.12	nd	nd	nd	nd
ADL	3.9±0.04	nd	nd	nd	nd
NFE	55.9±0.17	71.49	nd	65.37	nd
TDN _{IX} %	70.26±0.14	nd	66.04	nd	nd
DE _{IX} (Mcal/kg.)	2.98±0.01	nd	nd	nd	nd
DE _P (Mcal/kg.)	2.78±0.01	nd	nd	nd	nd
ME _P (Mcal/kg.)	2.36±0.01	4.36	nd	nd	nd
NE _{LP} (Mcal/kg.)	1.47±0.01	nd	nd	nd	nd

nd = not determined

Source: ^{1/} Ronglavanya (2006)
^{2/} Animal Nutrition Research and Development Center (2007)
^{3/} Pornchuleeya (2000)
^{4/} Srinorakutara *et al.* (2006)
^{5/} Baiden *et al.* (2007)

The information earlier show that the residual pulp which is separated from the starch in the screening process still contain a high amount of starch content and other nutrients which are necessary for animal growth particularly ruminant animals. Cassava pulp can be used as animal feed to reduce the production cost. Many studies have been done on the use of cassava pulp and leaves (cassava hay) in dairy cattle. Production performance of the dairy cattle satisfied in some level while few studies

have been done in beef cattle especially the feedlot cattle. Many feedlot producers try to reduce the production cost by supplementing cassava chips with cassava pulp especially when the price of cassava chips rise up. More researches on the use of cassava pulp in feedlot cattle are highly needed by the farmers.

2.5. Utilization of Cassava Leaves in Animal Nutrition

Cassava (*Manihot esculenta*, Crantz) is a tuber crop that grows widely in tropical and sub-tropical areas. It can easily thrive in sandy-loam soil with low organic matter, receiving low rainfall and high temperatures. It is there for a cash crop cultivated by small-holder farmers within the exiting farming systems in many countries (Wanapat, 1999). Cassava leaves are always through away during the harvesting of the cassava roots. It is estimated that 2.4 million tons of fresh cassava leaves or 0.72 million ton of dried cassava leaves are the waste product from cassava planting (adapted from Changleck and Juttupornpong, 2007). Cassava leaves have been used as a protein source when collected at tuber harvesting time. However, the intake and digestibility was low due to the high level of condensed tannins (Onwuka, 1992). Harvesting of cassava at an early growth stage (3 months) to make hay could reduce the condensed tannin content and increase protein content (25% of DM) resulting in a higher nutritive value (Wanapat *et al.*, 1997; Wanapat, 2003).

2.5.1. Planting, cutting and cultivation for cassava hay (CH) making

Planting cassava for haymaking was aimed to increase the whole crop digestible biomass and the tuber root as a by-product. Earlier work by Wanapat *et al.* (1997) demonstrated that planting cassava at 60 x 40 cm. between rows and intercropped with cowpea or leucaena could enrich soil fertility and be used as food and feed for humans and livestock, respectively. The initial cutting at 3 months was made and followed by subsequent cutting at every two months by hand breaking of the stem about 20-30 cm. above the ground (with 3-5 remaining branches). The fresh whole crop was directly sun-dried or chopped before sun-drying to obtain dry matter 80-90%. This might take 2-3 days but chopping helps shorten the drying process. Sun-drying also eliminate hydro-cyanic acid (HCN) by more than 90% and enhanced the palatability and long-term storage (Wanapat *et al.*, 1997).

2.5.2. Cassava leaf and cassava hay nutrition value

Cassava leaf meal may be classified as protein-, xanthophyll- and crude fiber-rich feed ingredient. Rochanaritipichet *et al.* (1988) reported that the protein content in leaves of 13 cultivars of cassava grow in Thailand ranged from 21.6-25.3% with the average of 23.7%. The protein content in cassava leaves varies according to the variety of cassava, soil fertility, and harvesting age of the plants. The amino acid composition of cassava leaf protein has high lysine content and is deficient only in methionine when compared to the complete protein. Although fresh

cassava leaves contain toxic levels of HCN, the process of drying the leaves reduced the HCN content to approximately 30 ppm. which is non-toxic to the animals.

Table 8 Chemical composition of cassava leaves and cassava hay

Item (%)	CLM ^{1/}	CH ^{2/,6/}	KU50 ^{3/}		RY72 ^{3/}		RY60	CH ^{5/}
			SC2	SC3	SC2	SC3	CH ^{4/}	RH
Moisture	9.28	13.7	17.87	19.67	18.02	19.18	-	13.70
DM	90.72	86.30	82.13	80.33	81.98	80.82	-	86.30
DP	20.02	22.00	nd	nd	nd	nd	nd	nd
CP	23.10	25.00	26.55	23.03	25.74	23.45	23.60	23.60
TDN	nd	65.00	nd	nd	nd	nd	nd	nd
CF	21.11	nd	18.59	22.17	19.72	21.46	nd	nd
EE	7.24	6.20	nd	nd	nd	nd	nd	nd
NDF	nd	44.40	47.55	48.90	46.30	47.60	41.30	44.30
ADF	nd	30.30	27.21	28.40	26.10	27.40	21.70	30.00
ADL	nd	5.80	12.60	13.60	11.70	12.70	nd	nd
Ash	5.72	12.50	9.68	9.78	9.65	10.60	nd	8.90
NFE	33.53	48.00	nd	nd	nd	nd	nd	nd
Calcium	0.99	2.40	nd	nd	nd	nd	nd	nd
Phosphorus	0.73	0.030	nd	nd	nd	nd	nd	nd
HCN (ppm)	30.50	380	nd	nd	nd	nd	nd	nd
Condensed tannins (%)	nd	3.90	nd	nd	nd	nd	39.70	nd
ME (kcal/kg.)	2,123.80	nd	nd	nd	nd	nd	nd	nd
Xanthophylls (mg/kg.)	660.00	nd	nd	nd	nd	nd	nd	nd

CL = Cassava leaf, CH = Cassava hay, KU50, RY72 and RY60 = cassava varieties,
 SC = Subsequent cutting,
 SC2 = First cutting at 3 months of growth and followed by every 2 months,
 SC3 = First cutting at 3 months of growth and followed by every 3 months
 RH = Harvested once at root harvest, nd = not determined

Source: ^{1/}Tongwittaya (1977)
^{2/} Wanapat (2005)
^{3/} Chanjula (2005)
^{4/} Chantaprasarn and Wanapat (2005)
^{5/} Wachirapakorn (2006)
^{6/} at younger stage of growth (3 months)

Wanapat and Rowlinson (2005) reported that cassava hay harvested at a younger stage of growth (3 months) contained up to 25% CP and had a good profile of amino acids. As presented in Table 8 and 9, cassava leaf and cassava hay contained

a relatively high value of nutrients particularly those of protein and amino acid profiles. When comparing cassava leaf (CL) and cassava hay (CH) with soybean meal (SBM) and alfalfa hay (AH), these amino acid profiles were relatively comparable. Lysine, glutamine, asparagine and arginine were higher in SBM but CH was higher with methionine and leucine. Nwokolo (1987) found that the protein content of cassava leaves was around 22% after a few days air-dry. Therefore we are able to replace soy bean and fish meal with cassava leaves into the feed concentrate to reduce the feed cost of poultry production. Du Thanh Hang (1998) reported that the ensiled cassava leaves contained up to 27% of crude protein (Table 10).

The protein in cassava leaves can be substituted for soybean protein in growing-finishing pig diets. The results have shown that cassava leaf meal can be included at the maximum level of 15% (Watcanakul *et al.*, 1988) and in growing pig diets with the level of 14% (Bui Huy Nhu Phuc *et al.*, 2000). Substitution of sun-dried cassava leaf meal for coconut oil meal at levels of up to 30% in the diet for growing and finishing pigs had no adverse effects on performance of the animals (Rajaguretal *et al.*, 1979). It has been found that cassava hay harvested at a younger stage of growth (3 months) contained protein up to 25% CP and with a good profile of amino acids. As presented in Table 9, cassava leaf and cassava hay contained relatively high value of nutrients particularly those of protein and amino acid profile (Wanapat, 2005; Kanto and Juttupornpong, 2007). Rumen degradability of cassava peels and cassava leaves were also found to be 83% and 84% respectively (Smith *et al.*, 1991).

Cassava hay, is hay which is produced at a young growth stage, 3 - 4 months and being harvested about 30 - 45 cm. above ground, sun-dry for 1 - 2 days until having final dry matter of at least 85%. The cassava hay contains high protein content, 20 - 27% CP and condensed tannins, 1.5-4%. It is used as a good roughage source for dairy, beef, buffalo, goats, and sheep by either direct feeding or as a protein source in the concentrate mixtures (Wanapat, 2005). Cassava hay has been used successfully as a source of high protein roughage for lactating cows to improve milk yield and quality and to reduce both cost and the use of concentrate (Wanapat *et al.*, 2001)

Chanjula (2005) reported the effects of varieties and subsequent cutting on yield and chemical composition of cassava hay. Both of total hay yield and CPDM yield were not significantly different by varieties and subsequent cutting. Cassava could produce from 4.98 to 6.15 t/ha of DM and 1.29 to 1.39 t/ha of CP. Crude Protein content in cassava plant ranged from 23.03 to 26.55% and was affected by different subsequent cutting regime (Table 11). Chantaprasarn and Wanapat (2005) reported the effect of different harvest intervals of cassava foliage on cassava root and foliage yield, and its chemical composition under traditional cultivation. Based on this study, it was concluded that different harvest intervals of cassava foliage had no major effect on quality, but affected the quantity of foliage and root yield. Planting cassava for making cassava hay as a protein resource for year-round feeding could be potentially more profitable under small-holder farming systems (Table 12).

Chantaprasarn and Wanapat (2005) reported that feeding fat by using sunflower oil in concentrate with cassava hay for lactating cows could be a way to meet energy nutrient requirements and to improve rumen ecology as well as milk yield and quality. Wanapat *et al.* (2000) found that increasing levels of cassava hay from 0.6 to 1.7 kg/hd/d could reduce levels of concentrate from 0.1 to 1.6 kg/hd/d., respectively without changing levels of milk yield. Moreover, feeding cassava hay on ad libitum resulted in similar result and could further reduce concentrate use.

Table 9 Chemical composition of cassava leaves

Nutrient	% ^{1/}	Amino acids	% in protein ^{2/}
Moisture	9.28	Lysine	6.77
Crude protein	23.10	Methionine	1.68
True protein	20.02	Tryptophan	1.77
Crude fiber	21.11	Threonine	4.83
Ether extracts	7.24	Leucine	8.87
Ash	5.72	Isoleucine	4.93
NFE	33.53	Arginine	5.70
Calcium	0.99	Phenylalanine	5.68
Phosphorus	0.73	Histidine	2.40
HCN(ppm)	30.50	Valine	5.66
ME(kcal/kg)	2,123.82		
Xanthophylls(mg/kg)	660		

Source: ^{1/}Tongwittaya (1977)

^{2/}Rogers and Milner (1963) cited by Kanto and Juttupornpong (2007)

Table 10 Chemical composition of feeds

Item	Dry matter %	N*6.25 % in DM	Crude fiber % in DM	HCN mg/kg DM
Ensiled cassava leaves	35.00	27.00	15.30	70.70
Duckweed	6.48	30.10	8.30	nd
Sweet potato vines	13.60	17.70	10.50	nd
Rice bran	87.60	14.80	8.45	nd
Cassava root meal	90	2.00	3.25	26.70
Brewers' grains	21.00	25.30	12.70	nd
Ensiled cassava root	40.20	1.50	0.92	65.30

Source: Du Thanh Hang (1998)

Table 11 Effects of cassava varieties and subsequent cutting on fresh and dry fodder and protein yield of cassava hay

Item	KU50		RY72	
	KU50-SC2	KU50-SC3	RY72-SC2	RY72-SC3
Fresh yield (t./ ha.)				
Total	27.59	30.76	29.08	28.68
Leaf	12.96	13.79	13.56	12.67
Branch	7.60	6.29	7.85	5.57
Stem	7.03	10.68	7.66	10.44
Dry matter yield (t./ ha.)				
Total	4.98	6.15	5.53	5.48
Leaf	2.99	3.27	3.18	2.97
Branch	1.01	1.17	1.19	0.85
Stem	0.98	1.70	1.16	1.66
Crude protein	1.31	1.39	1.35	1.29

KU50 and RY72 = cassava varieties, SC = Subsequent cutting.

SC2 = First cutting at 3 months of growth and followed by every 2 months.

SC3 = First cutting at 3 months of growth and followed by every 3 months.

Source: Chanjula (2005)

2.6. Cyanide and tannins content of cassava tuber and leaves

Cassava leaves are the by-product of cassava plants after the harvesting of the roots. The fresh leaves which are normally the cassava tops contain approximately 60 - 70% moisture, have high levels of HCN and are not appropriate for feeding to the animals. However, HCN content in cassava leaves can be reduced by sun-drying and ensile method. Dry cassava leaves, which are produced either by 1-2 days sun-drying or by an artificial drier, with not more than 10% moisture content, are a good feed ingredient which supply not only protein and crude fiber but also pigment or xanthophyll for the animals (poultry). Fasuyi (2005) reported the results of different processing methods including sun-drying (SND), oven-drying (OVD), steaming (STM), shredding (SHD), steeping (STP) and a combination of these methods to deliberately reduce the high level of cyanogenic glucosides present in the cassava leaves. A combination of SHD and SND (SHD+SND) seem to be the most effective technique of reducing the cyanide content.

Condensed tannins and hydrocyanic acid (HCN) concentrations were low in both of cassava leaves and cassava hay. Sun-drying could remarkably reduced HCN (Fasuyi, 2005). Digestibility and intake studies in cattle resulted in relatively high values, which demonstrated that cassava hay was palatable and digestible. Condensed

tannins (CT) and hydrocyanic acid were generally found in high value in matured cassava leaf but were lower in cassava hay harvested at younger stage (Wanapat and Rowlinson, 2005).

Table 12 Effects of different harvest intervals of cassava foliage on cassava foliage and root yield

Item	Harvest interval			
	RY60-H1	RY60-H2	RY60-H3	RY60-0H4
Cassava foliage				
DM from fresh foliage, %	30.20	29.40	29.70	29.10
Fresh yield, t./ha.	0.80	3.10	9.00	13.80
DM yield, t./ha.	0.30	0.90	2.70	4.00
Cassava root				
DM from fresh root, %	37.80	41.70	36.30	31.90
Fresh yield, t./ha.	25.10	19.80	17.40	15.20
DM yield, t./ha.	9.50	8.20	6.30	4.90
Starch, %	24.70	25.30	20.10	19.30

RY60 = cassava variety

H1 = Harvested once at root harvest, H2 = Harvest 2 times at 3 months of growth and at root harvest.

H3 = Harvest 3 times at 3 months of growth, 3 months thereafter and at root harvest.

H4 = Harvest 4 times at 3 months of growth, every 3 months thereafter and at root harvest.

Source: Chantaprasarn and Wanapat (2005)

Kanto and Juttupornpong (2007) have been reported that fresh cassava tuber and leaf contain cyanogenic glycosides, mainly linamarin and a minimal amount of lotaustalin, which are hydrolyzed into glucose and hydrocyanic acid (HCN) by the activity of the linamarase enzyme when the tuber is damaged or broken into small pieces. The released HCN is evaporates into the atmosphere so the level of HCN in the cassava products is reduced. Wongwarat *et al.* (2005) have studied the free cyanide content in nine different tissues (shoot apex, young leaves, mature leaves, old leaves, young petioles, mature petioles, old petioles, peels and pulp of roots) of four cultivars of cassava (Rayong 60, Rayong 72, Rayong 2 and Hanatee) was determined. The results showed a wide variation of free cyanide content in different tissues of cassava. In all four cultivars, the shoot apex had higher free cyanide content than other tissues. Based on the free cyanide content in the root pulp, Rayong 60 and Rayong 72 were classified as high-cyanide cultivars and Rayong 2 and Hanatee low-cyanide cultivars. Data from this preliminary study is useful for future study towards the improvement of cassava and understanding the processes of synthesis, transport and metabolism of cyanogenic glucosides (Table 13).

Table 13 Free cyanide content in the different tissue of four cassava cultivars

Cultivar	Cyanide content ($\mu\text{g HCN/g}$ fresh weight)								
	shoot apex	young leaves	mature leaves	old leaves	young petiole	mature petiole	old petiole	peel	pulp
R6O	123.886 ± 24.886	41.209 ± 9.146	nd	nd	44.95 ± 4.87	24.52 ± 9.15	4.27 ± 2.31	25.57 ± 5.25	19.97 ± 3.46
R72	163.815 ± 49.003	53.856 ± 12.958	48.433 ± 9.125	45.23 ± 4.75	144.13 ± 17.07	19.50 ± 8.28	5.19 ± 3.19	48.97 ± 25.00	27.68 ± 21.6
R2	80.691 ± 29.522	nd	nd	nd	26.21 ± 8.47	15.83 ± 10.62	1.39 ± 0.85	10.30 ± 4.94	3.83 ± 1.9
Hanatee	223.714 ± 27.570	nd	nd	nd	114.59 ± 14.68	90.38 ± 3.87	40.50 ± 5.31	10.61 ± 2.00	4.10 ± 1.37

Source: Wongwarat *et al.* (2005)

The “cyanide scare” associated with acute toxification when food substance rich in cyanide is ingested at high levels seemed to be obviated by a combination of processing methods (SHD: Shredding + SND: Sun drying) (Fasuyi, 2005).

Buaphan (2003) found that increasing the levels of cassava chips in the diet of dairy cattle increased the levels of HCN and aflatoxins. Increasing cassava chip levels in the diets have significantly increased ($P < 0.05$) the content of thiocyanate and lactoperoxidase in the milk, which have resulted in the significant decrease ($P < 0.05$) in the content of aflatoxins M1 and coliform bacteria in the milk as well as the clear tendency of the lower total somatics and total bacterial cells counts in the milk. It could be concluded that increasing of cassava chips in the dairy cow diet would naturally increase the lactoperoxidase system which includes thiocyanate, lactoperoxidase and hydrogen peroxide in the milk and has provided many beneficial effects including degradation of aflatoxins other toxins, control of microorganisms especially pathogenic microorganisms in the milk, health improvement of milk gland, prevention of mastitis and significantly improved quality and storage or keeping quality of milk. Cassava including cassava chips, pulp and leaves are therefore an ideal basal feed ingredient for cattle.

Moreover, as has been reported by Claesson (1994) that milk thiocyanate was required in the lactoperoxidase system in milk to help preserve the shelf-life and the optimal range of milk thiocyanate should not exceed 20 ppm. Feeding dairy cows with cassava hay as a supplement, has been shown that milk thiocyanate was 19.5 ppm, however, more researches need to be further conducted in order to pin-point the role of residual HCN in cassava on milk thiocyanate.

Barry and Manley (1984) and Reed (1995) reported that if condensed tannins in the feed exceeded 6% of dry matter, it would reduce feed intake and digestibility.

If condensed tannins contained between 2-4% DM, it would help to protect protein from rumen digestion thereby increasing by-pass protein.

Internal parasites in ruminants raised in the tropics have been found to be one of the big constrains, apart from feed availability. Furthermore, using commercial drenching could result in high cost of production. The studied on using feeds containing condensed tannins have been shown to reduce internal parasitic egg counts in cattle, buffalo, sheep and goats (Wanapat, 2000; Netpana *et al.*, 2001). Wanapat and Khampa (2006) studied the effects of cassava hay in high-quality feed block as anthelmintics in steers grazing on ruzi grass and could reduce the internal parasitic egg counts as shown in Table 14.

Table 14 Effects of supplementation of high-quality feed block with or without cassava hay as anthelmintics in dairy steers grazing on Ruzi grass

Parasitic eggs/g of fresh feces Week-post feeding	HQFB1+Ivomec-F*	HQFB2**
-2	560	555
-1	558	557
1	550	550
2	212	487
3	162	387
4	125	351
5	112	325
6	110	320
Mean	211.8	403.3
Reduction(%)	63.2	27.6
ADG(kg/hd/d)	0.41	0.45

* HQFB1= High-quality feed block without cassava hay.

**HQFB2= High-quality feed block with cassava hay.

Source: Wanapat and Khampa (2006)

Cassava could be cultivated to produce cassava hay with high nutritive value. Inter-cropping cassava with food-feed could further increase biomass yield and enrich soil fertility. Condensed tannins contained in cassava hay demonstrated potential as a tannin-protein complex thus to increase rumen by-pass protein and to reduce GI nematodes egg count. Feeding cassava hay as a supplemental high protein source could increase milk yield and compositions and could significantly reduce concentrate use. On-farm research with small-holder farmers show a promising establishment and development of cassava hay production on farm. Harvesting of whole crop at an earlier stage and subsequent cuttings to produce hay resulted in increasing protein to energy ratio in animal feeding (Wanapat, 2005).

3. The quality of beef produced under Thai market system

The qualities of beef produced under Thai market systems are different depending on the production system and the requirements of the market. Each quality is good enough and fit the needs of consumers. The consumers, restaurants, fast food restaurants and others can select and utilize all kinds of beef depending on their cooking style and price range. The qualities of beef are classified as followed. (Yimmonkol, 2003; Sretthakul and Opaspattanakij, 2005)

3.1. Ponyangkham Beef

Ponyangkham beef is produced by the Ponyangkham Beef Producer Cooperative (PBPC, 2008) which located at Sakonnakhon Province. The quality of this beef is fit for the need of supermarkets, restaurants, discount stores and etc. The specification and quality of the Ponyangkham beef is classified as followed.

1. From $\geq 50\%$ Charolais crossbred (or Limousine or crossbred are also required)
2. High marbling score
3. Average ≥ 3 years of age
4. The retail cuts of the carcass are also have marbling
5. Chilled more than 7 days
6. More tenderness due to the marbling
7. Marbling line is clearly
8. Meat color is bright red
9. Standard slaughterhouse and dressing room is require

3.2. KU. Beef (Prime quality)

KU. Beef is produced by the KU. Kamphaeng Saen Campus Beef Producer Cooperative Ltd. (KU. KBPC) which located at Buffalo and Beef Production Research and Development Center (BRDC), Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom Province (KU. KBPC, 2008). The specification and quality of the KU. Beef is classified as followed.

1. From Kamphaeng Saen beef steer
2. Fair in marbling score
3. Insist in tenderness due to the young steer and longer chill period of 14 days or more
4. ≤ 3 years of age

- of steer
5. Meat color is bright red and fat color is creamy white due to the age
 6. Slaughterhouse and dressing room standards are required
 7. Food safety and traceability standard are required

3.3. Beef Pro. (Brahman crossbred of 50% crossed or more)

Beef Pro. is produced by Ruamkaset Koneur Co ltd. (Farm Lung Chao) which located at Supanburi Province. The specification and quality of the Beef Pro. is classified as followed.

1. $\geq 50\%$ of Brahman crossbred young bull
2. No marbling due to the young bull instead of steer
3. Average age of 2 years
4. The retail cuts from the carcass have no marbling or fat which can be processed as meat ball or others
5. The tenderness is fair and should be chilled longer
6. High moisture content
7. Meat color is rather dark red
8. Fat color is creamy white due to the age young bull
9. Final weight before slaughtering is about 100 kg. less than temperate crossbred
10. Slaughtering under slaughterhouse standards

3.4. Brahman crossbred fed with ensiled pineapple waste

The quality of beef produced from the Brahman crossbred (young bull) fed with ensiled pineapple waste known as local quality usually produced near the pineapple canneries especially at the central and east part of Thailand. The specification and quality of beef is classified as followed.

1. Meat color is bright red
2. More tenderness within 1-2 days of chilling time
3. More exudates
4. No marbling
5. Slaughtering at local slaughterhouse

3.5. Native cattle with pasture feeding

1. Meat color is rather dark red
2. Smooth and fine muscle fiber
3. No marbling and less fat content at any part of carcass
4. Low moisture content
5. Slaughtering at local slaughterhouse

3.6. Local quality beef I (Komun I)

Local quality beef I is usually produced from retired bull and cow or live cattle imported from neighbor countries (> 90% from Myanmar) and fed in feedlots for 2-3 months with concentrate and roughage or total mixed ration. The central part of Thailand is the center of this production where many kinds of waste product from agriculture and agricultural factories can be used as roughage such as pineapple waste, baby corn stover, cassava pulp, cassava leaves and etc. The specification and quality of local quality beef I or Komun I is classified as followed.

1. Average age is more than 5 years (mostly > 10 years)
2. Coarse muscle fiber
3. Fat color is yellow due to the age of feedlot cattle and high fat thickness especially the rib fat
4. No marbling in contrast with fat thickness (carcass fat and rib fat)
5. Low tenderness due to the age of feedlot cattle
6. Sent to the markets (local market) immediately after slaughtering and no requirement of chilling or aging
7. Strong smell of meat in contrast with the others
8. Slaughtering at local slaughterhouse

3.7. Local quality beef II (Komun II; Standard quality)

Local quality beef II is usually produced from young bulls (not castrated), mostly are crossbred Brahman or any crossbred young bull and fed in feedlots for 3-4 months with concentrate and roughage or total mixed ration. The quality of this beef is fit for the needs of fresh markets in Bangkok and also the supermarkets and discount stores. The specification and quality of local quality beef II or Komun II is classified as followed.

1. Young bull of Brahman crossbred (not castrated) or dairy steer
2. Average age \leq 3 years
3. Coarse muscle fiber of Brahman crossbred and fine muscle fiber of dairy steer

4. No marbling, less of carcass fat and rib fat due to the castration is not required

5. Chilling period is not required

6. More tenderness than the local quality I (Komun I) and less than KU. Beef or Ponyangkhram Beef.

7. Smell of meat is not strong

8. Sent to the markets immediately after slaughtering without chilling

9. Slaughtering at standard slaughterhouse

MATERIALS AND METHODS

Research and development projects on improvement of potential use of dried cassava pulp and cassava leaf meal in concentrate of feedlot cattle are divided into 6 projects as follow

Project I. Observation on the general information of cassava pulp produced and cassava pulp and leaf meal used as cattle feed in the central part of Thailand

Materials

1. The objective farmers were the farmers who raised cattle in the central area of Thailand.
2. Data collecting was done through the questionnaires by direct interview.
3. Digital camera used for recording the image.

Methods

Objective locations and farmers

The objective location was the central part of Thailand where approximately 60 - 70% of local quality feedlot cattle, Komun I. and Komun II., are produced (Sretthakul and Opaspattanakij, 2005; Yimmongkol, 2002). There are many cassava starch and sweetener factories located in Ratchaburi, Kanchanaburi, Nakhon Pathom and Pathumthani (TTSA, 2008b) where the by-product used by the farmers was easy to follow up. The observation covered Nakhon Pathom, Ratchaburi, Phetchaburi, Suphan Buri, Kanchanaburi, Pathumthani, Nakhon Sawan, Prachuab Khiri Khan, Chon Buri and Rayong provinces.

Data collecting

The observation was done by tracking of cassava pulp purchasing from factories to dairy and feedlot farms by interviewing the farmers. The study focused on dairy and feedlot farms while the breeding stock of the small holders was neglected because feed supplement was unnecessary.

Cassava Starch Factory

Four cassava starch factories which located in the central part of Thailand were selected for general information study including 1 factory located in Ratchaburi, 2 factories in Kanchanaburi and 1 factory in Uthaitanee.

Data collecting period

September 2005 – September 2006

Project II. Preliminary evaluation on various methods of using ensiled cassava pulp as main energy source for feedlot cattle

Materials

1. Ensiled cassava pulp, corn stover and leucaena leaves were used as feed ingredients in the treatment diets.

2. Individual feeding stalls with 4 x 4 m². at Buffalo and Beef Production Research and Development Center, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom.

3. 15 Brahman-native crossbred young bulls with initial live weight of 312.53 ± 10.17.

4. Treatment diets composed of ensiled cassava pulp (ECP) and ECP mixed with the other roughages as follow.

ECP1: Ensiled cassava pulp and supplemented with 1 kg. of leucaena leaf meal/day.

ECP2: Ensiled cassava pulp mixed with corn stover in the ratio of 2:1 by weight.

ECP3: Ensiled cassava pulp mixed with corn stover, leucaena leaf meal and sugarcane bagasse in the ratio of 20:7:2:1 by weight.

All of the treatment diets were ensiled for 14 days.

Methods

Experimental animals

15 Brahman-native crossbred young bulls at an average age of 2 years and initial weight of 312.53 ± 10.17 were used. They were treated for internal and external parasites with Ivomex-F intramuscularly, vaccinated against Foot and Mouth Disease (FMD) and were kept individually in feeding stalls where feed and water was provided. The animals were assigned using stratified random sampling to one of the

three treatment diets such that there were five animals per feed treatment. Each animal was fed with the treatment diets for two weeks before the experiment started.

Experimental design

The animals were randomly divided into 3 groups of 5 animals each and feedlot cattle were randomly allotted to receive one of three treatment diets according to a Completely Randomized Design (CRD) (SAS, 2003; Chantalakkana, 2006).

Treatment diets

The feeding period was 105 days. The control treatment diet (ECP1) was ensiled cassava pulp supplemented with 1 kg. of leucaena leaf meal. ECP1 and the other treatment diets were fed to the animals *ad libitum* and supplemented with mineral block each day. The other 2 treatments were ECP2: ensiled cassava pulp mixed with corn stover in the ratio of 2:1 by weight and ECP3: ensiled cassava pulp mixed with corn stover, leucaena leaf meal and sugarcane bagasse in the ratio of 20:7:2:1 by weight. The treatment diets were based on the feeding methods used by many local feedlot producers to evaluate the effectiveness of the feeding methods and basic information for further research.

Feeding

A 14-day adaptation period preceded the growth studies. During the adjustment period the treatment was gradually substituted for roughage (para grass; *Brachiaria mutica*) until the total substitution was completed within 2 weeks. The experimental period began at 3rd week. Feed and water were provided *ad libitum* and mineral lick was accessed at all time for 105 days.

Data collection

The daily feed offered and refused was determined. Live weight was measured monthly before morning feeding. Palatability of the treatment diets was also studied over 7 days a month by recording the feed refusals before the second daily feeding time.

Chemical analysis

Proximate analysis of feed ingredients and experimental diets was determined by using the methods of AOAC (1990).

Statistical analysis

All data was subjected to analysis of variance using the Completely Randomized Design (CRD) (SAS, 2003; Chantalakkana, 2006) to determine the effect of treatment diets on the various parameters studied. When significant F-values of the treatment effects were found, then differences among means were compared by using the Duncan's Multiple Range Test.

Experimental Station

Buffalo and Beef Production Research and Development Center, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom.

Animal Nutrition Research and Development Center, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom.

Experimental period

4 July – 17 October 2004

Project III. Effects of replacing cassava chip with dried cassava pulp in concentrate on feeding performance, carcass quality and economic return of feedlot cattle

Materials

1. Twenty Brahman-native crossbred young bulls at an average age of 2 years and initial weight of 298.08 ± 11.30 kg.

2. Individual feeding stalls with 4×4 m². at Buffalo and Beef Production Research and Development Center, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom.

3. The control concentrate (CTRL) consisted of cassava chips as an energy source. The other 3 treatments were concentrate in which cassava meal was replaced by DCP at 10, 20 and 30% by weight (Table 15).

4. Scale instrument of maximum 1000 kg. and 30 kg. for measuring body weight and the dietary feed weight and refused, respectively.

5. Laboratory equipments for proximate analysis of feed compositions (AOAC Method)

6. Laboratory equipments for analyzing digestibility coefficient (according to the method of Ensminger and Olentile, 1980)

7. Laboratory equipments for determining bulk density of dietary feeds (Khajarearn and Khajarearn, 1999).

8. Slaughter house and equipments for carcass evaluation and measurement.

Table 15 Feed composition of the experimental concentrate (I.)

Ingredient (kg.)	CTRL	DCP10	DCP20	DCP30
Cassava chips	45.2	35.2	25.1	15.1
Dried cassava pulp	-	10	20	30
Dried brewery grain	18	18	18	18
Corn	14	14	14	14
Leucaena leaf meal	10	10	10	10
Molasses	8	8	8	8
Urea	1.6	1.6	1.7	1.7
Salt	0.4	0.4	0.4	0.4
Dicalcium phosphate	0.5	0.5	0.5	0.5
Zeolite	2.0	2.0	2.0	2.0
Premix	0.2	0.2	0.2	0.2
Sulphur	0.1	0.1	0.1	0.1
Total	100	100	100	100

Methods

Experimental animals

Twenty Brahman-native crossbred young bulls at an average age of 2 years and initial live weight of 298.08 ± 11.30 were used. They were treated for internal and external parasites with Ivomex-F intramuscularly, vaccinated against Foot and Mouth Disease (FMD) and were kept individually in feeding stalls where feed and water was provided *ad libitum*. The animals were assigned using stratified random sampling to one of four treatment diets such that there were five animals per feed treatment. Each animal was fed with treatment diets for two weeks before the experiment started.

Experimental design

The animals were randomly divided into 4 groups of 5 animals. Each group of animals was randomly allotted to receive one of the four treatment diets for a period of 120 days according to a Completely Randomized Design (CRD) (SAS, 2003; Chantalakkana, 2006;).

Treatment diets

Each group of the animals was randomly fed one of the experimental diets. The control concentrate (CTRL) in which cassava chips was used as an energy source. The other 3 treatment diets were concentrate in which cassava chips was replaced by DCP at 10 (DCP10), 20 (DCP20) and 30% (DCP30), respectively (Table 15). Each of treatment diets was fed to the animals *ad libitum* and supplemented with 3 kg. of para grass (*Brachiaria mutica*). Water and mineral lick was accessed at all time. Every experimental diet was formulated to contain the same level of crude protein (14%) to satisfy the requirements for feedlot cattle for 1- 1.4 kg. /day of weight gain (Kearl, 1982).

Ingredients in the experimental diets consisted of cassava chips, dried cassava pulp, dried brewery grain, corn meal, leucaena leaves, molasses, urea, salt, dicalcium phosphate, Zeolite, mineral premix and sulfur (Table 15).

Feeding

A 14 day feeding adaptation period was required before the growth studies. During the adaptation period, the treatment diets were gradually introduced to the animals by reducing the level of roughage (para grass : *Brachiaria mutica*) and feeding more treatment diets for every second day. The animals were fully on the experimental diets in the beginning of third week and fed *ad libitum* daily at 08.00, 12.00 and 18.00 hours and supplement with 3 kg. of para grass to maintain the rumen function of the experimental animals. The experimental diets and grass were fed in the same feeding trough. Each animal had access to a mineral-vitamin lick and water at all times.

Data collection

Data collection was done from the third week of the experimental for a period of 120 days. Feed offered and refused was recorded daily to measure feed intake. Daily intake of concentrate and roughage were recorded. Samples of the feed were taken weekly and weekly samples were bulked for laboratory analysis and determined the bulk density (Khajarern and Khajarern, (1999). Live weight was recorded monthly before morning feeding. The animals were bled from the jugular vein monthly before feeding and the blood samples were analyzed to examine the effect of the treatment diets on some blood constituents. Palatability of the treatment diets was also studied 7 days consecutively a month by the determination of the treatment diets offered and refusal.

Digestibility studies

After two weeks of the adjustment period, the experiment was started. Feces were collected for seven days at 30 and 90 days of the feeding period (120 days) which started from 6.00 am. until 24.00 pm. Feed intake and fecal output were measured at the same time each day. Amount of feeds which were offered at 08.00, 12.00 and 18.00 hours were weighed and sampled (10%) daily during the collection period and the samples were kept frozen. At the end of the period the sample of treatment diets were thawed, bulked and mixed thoroughly. Nutrient composition of the treatment diets were proximately analyzed (AOAC, 1990). The entire daily fecal output of each animal was collected, weighed and mixed thoroughly. A sample (10%) taken for daily dry matter determination in a forced-draught oven at 60°C for 24 hours. At the end of the experiment the total feces stored per animal was bulked, thoroughly mixed, ground to pass a 1 mm sieve and sub-sampled for chemical analysis. Feces samples were taken for analyzing the digestibility coefficient of DM, OM, CP and CF (Ensminger and Olentile, 1980) and chemical analysis according to the method of AOAC (1990). The animals were weighed at the beginning and end of the collection period.

Carcass examination, carcass measurement and analysis

At the end of the experiment, all animals were weighed, held overnight off feed and slaughtered the following day (Kantapanit, 1986) at a local standard slaughter house (Ratchaburi Province). After skinning and evisceration, the rumen was cut open and the walls inspected for ulcers and scaring. Warm carcass weight, hide weight and visceral weight were recorded and each carcass was cut to determine the retail cuts percentage, lean meat, fat, bone and skin and the amounts recorded (Kantapanit, 1986).

Chemical analysis

Proximate analysis of feed ingredients, experimental diets and feces were determined by using the methods of AOAC (1990). Digestibility coefficients were determined by using the method of Ensminger and Olentile, (1980).

Statistical analysis

All data was subjected to analysis of variance using the Completely Randomized Design (CRD) (SAS, 2003; Chantalakkana, 2006) to determine the effect of treatment diets on the various parameters studied. When significant F-values for treatment effect were found, then differences among means were compared by the Duncan's Multiple Range Test.

Experimental Station

1. Buffalo and Beef Production Research and Development Center, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom.
2. Department of Animal Science, Faculty of Agriculture at Kamphaeng Saen and Animal Nutrition Research and Development Center, Kasetsart University, Kamphaeng Saen Campus.
3. Local slaughter house at Ratchaburi Province.

Experimental period

January – April 2005

Project IV. Effects of dried cassava pulp as a main source of energy in concentrate on feeding performance, economic return, carcass composition and some beef eating qualities of feedlot cattle

Materials

1. Fifteen Brahman-native crossbred young bulls at an average an age of 2 years and initial weight of 277 ± 10.36 kg.
2. Individual feeding stalls with 4×4 m². at Buffalo and Beef Production Research and Development Center, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom.
3. The control concentrate (CTRL) contained cassava chips as an energy source. The other 2 treatments were concentrate in which cassava meal was replaced by dried cassava pulp (DCP) at 50 and 100% by weight, respectively. (Table 17).
4. Scale instrument of maximum 1000 kg. and 30 kg. for measuring animal body weight and the dietary feed weight and refusaed, respectively.
5. Laboratory equipments for analyzing digestibility coefficient (method of Ensminger and Olentile, 1980)
6. Laboratory equipments for proximate analysis of feed compositions (AOAC, 1990)
7. Laboratory equipments for determining bulk density of treatment diets (Khajarern and Khajarern, 1999).

8. Laboratory equipments for blood samplings, blood glucose, blood urea nitrogen and Triiodothyronine Hormone (T₃) analysis.
9. Suction equipments for rumen fluid samplings
10. Laboratory equipments for analyzing of ammonia nitrogen (Kjedahl method) and volatile fatty acids (Gas Chromatography by the method of Miyazawa *et al.*, 2007) of the rumen fluid
11. pH meter (WTW inoLab Ph 720 Model) for measuring pH of rumen fluid
12. Olympus microscope BX 50 Model and laboratory equipments for determining the population of microbial rumen
13. Slaughter house and equipments for carcass examination and measurement.
14. Real time ultrasound (Pie Medical 100 Falco, U.S.A.) for measuring loin eye area, loin thickness and rib fat thickness (Gresham, 2001).
15. Marbling score of National Bureau of Agricultural Commodity and Food Standards (2005)
16. Subjective meat color score of Japan Meat Grading Association (1990) and Smith *et al.* (2001)
17. Subjective fat color score of Japan Meat Grading Association (1990)
18. Warner Bratzler Shear device (Challion; G-H ELEC Co. Ltd., U.S.A.) for measuring beef tenderness
19. Well experience taste panelists from Buffalo and Beef Production Search and Development Center, Animal Produce Research and Development Center, KU Kamphaeng Saen Campus Beef Producer Cooperative Ltd. and Department of Animal Science, Kasetsart University, Kamphaeng Saen Campus were invited for sensory evaluation.

Methods

Experimental animals

Fifteen Brahman-native crossbred young bulls at average age of 2 years and initial weight of 277 ± 10.36 kg. were used. They were treated for internal and external parasites with Ivomex-F intramuscularly, vaccinated against Foot and Mouth Disease (FMD) and were kept individually in feeding stalls where feed and water is provided. The animals were assigned using stratified random sampling to one of the three treatment diets such that there were five animals per feed treatment. Each group of animals was fed with treatment diet for two weeks of feeding adaptation period before the experiment started.

Table 16 Proximate analysis of the experimental cassava pulp and cassava leaf meal (DM basis)

Composition (%)	Cassava Pulp	Cassava Leaf Meal	Para grass (<i>Brachiaria mutica</i>)
Dry matter	89.40	89.70	32.25
Organic matter	95.58	91.20	91.44
Crude protein (N X 6.25)	1.970	24.00	5.48
Crude fiber	13.10	17.00	28.24
Crude fat	0.48	4.60	1.50
Ash	4.03	8.80	8.56
NDF	32.4	46.30	76.77
ADF	7.2	26.85	46.67
Lignin	-	-	5.43
Calcium	0.72	0.79	0.24
Total phosphorus	0.36	0.52	0.09

Table 17 Feed composition of the experimental concentrate (II.)

Ingredient (kg.)	CTRL	DCP 50	DCP 100
Cassava meal	46.6	25.4	-
Dried cassava pulp	-	25	46.4
Cassava leave meal	15.0	15	15
Rice bran	12.0	10	12
Corn	12.0	10	12
Molasses	8.0	8	8
Urea	1.9	2.1	2.1
Zeolite	2.0	2.0	2.0
Salt	1.0	1	1
Dicalcium phosphate	1.0	1	1
Premix (trace mineral)	0.4	0.4	0.4
Sulphur	0.1	0.1	0.1
Total	100	100	100

Experimental design

The feedlot cattle were randomly divided into 3 groups of 5 animals and were randomly allotted to receive one of three treatment diets according to a Completely Randomized Design (CRD) (SAS, 2003; Chantalakkana, 2006).

Treatment diets

The feeding period was 150 days. The control concentrate (CTRL) consisted of cassava chips used as an energy source. CTRL and treatment diets were fed to the

animals *ad libitum* and supplemented with 3 kg. of para grass (*Brachiaria mutica*) daily. The other 2 treatments were concentrate in which cassava meal was replaced by dried cassava pulp (DCP) at 50 and 100% and were assigned as treatment diets of (DCP50 and DCP100), respectively (Table 17). All treatment diets were isonitrogenous and formulated to contain nutrient according to feedlot cattle requirement (Kearl, 1982).

Ingredients in the experimental diets consisted of cassava chips, dried cassava pulp, corn meal, rice bran, cassava leave meal, molasses, urea, salt, dicalcium phosphate, Zeolite, mineral premix and sulfur (Table 16 and 17).

Feeding

A 14-days adaptation period preceded the growth studies. During the adjustment period the diets were gradually introduced to the animals by reducing the level of roughage (para grass: *Brachiaria mutica*) and feeding more treatment diet every second day. They were put on the experimental diets fully in the third week and fed *ad libitum* daily at 08:00, 12.00 and 18.00 hours and supplement with 3 kg. of para grass to maintain the rumen function of the experimental animals. The experimental diet and grass were fed in the same feeding trough. Each animal had access to a mineral-vitamin lick and water at all times.

Data collection

Data was collected for 150 days starting from the third week. Feed offered and refusals were weighed daily to measure feed intake. Daily intake of concentrate and roughage was recorded. Samples of the feed were taken weekly and weekly samples were bulked for laboratory analysis and determined the bulk density (Khajarearn and Khajarearn, (1999). Live weight was measured monthly before morning feeding. The animals were bled regularly from the jugular vein at 0, 60 and 120 days before feeding and the blood samples analyzed to examine the effect of the treatment diets on some blood constituents (blood glucose, blood urea nitrogen and Triiodothyronine Hormone (T₃). Rumen fluid samples were collected to analyze for ammonia nitrogen by Kjeldahl Method (Bromner and Keeney, 1965), volatile fatty acids by the method of Miyazawa *et al.*, (2007) and pH was determined by WTW inoLab Ph 720 Model. Microbial rumen was also counted for the studying of the rumen ecology by the method of Galyean (1989), Dehority (1984) and Dickinson *et al.* (1997) with an Olympus microscope BX 50 Model. Palatability of the treatment diets was also studied for 7 days consecutively a month each month by checking the feed refusals before the second daily feeding time. Rumen fluid samples were collected at 60 and 90 days of the experimental period to determine pH by WTW inoLab Ph 720 Model.

Digestibility studies

After two weeks of adjustment period in the feeding stalls, the experiment was started. Feces were collected for seven days at 60 and 120 days of feeding period (150 days) which started from 6.00 am. Until 24.00 pm. Feed intake and fecal output were measured at the same time each day. Feeds which were offered at 08:00, 12.00 and 18.00 hours were weighed and sampled (10%) daily during the collection period and the samples were kept frozen. At the end of the period the sample feeds were thawed, bulked and mixed thoroughly. Nutrient consumptions of the treatment diets were proximate analyzed (AOAC, 1990). The entire daily fecal output of each animal was collected, weighed, mixed thoroughly and a sample (10%) was taken for daily dry matter determination in a forced-draught oven at 60 °C for 24 hours. At the end of the experiment the total feces stored per animal were bulked, thoroughly mixed, ground to pass a 1 mm sieve and sub-sampled for chemical analysis. Feces samples were taken for analyzing the digestibility coefficient of DM, OM, CP, CF, NDF and ADF (Ensminger and Olentile, 1980) and chemical analysis according to the method of AOAC (1990). The animals were weighed at the beginning and end the of the collection period.

Economic analysis

All of the investments of the feedlot cattle production were recorded such as cost of feedlot cattle, health management, total feed cost, transportation, labour cost, public utility, miscellaneous and others for economic analysis (Livestock Development Department, 2005).

Chemical analysis

Proximate analysis of feed ingredients, experimental diets and feces were determined by using the methods of AOAC (1990). The digestibility coefficients were determined by using the method of Ensminger and Olentile, 1980. Rumen fluid samples were collected at 60 and 90 days of experimental period to analyze ammonia nitrogen by Kjeldahl Method (Bromner and Keeney, 1965) and volatile fatty acids by the method of Miyazawa *et al.* (2007).

Slaughtering and carcass measurement

The feeding period was 150 days. The animals were weighed (at the end of the experiment), withdraw the feed overnight off feed and slaughtered the following day at a local standard slaughter house (J. Livestock Farm, Suphanburi) by the method of Kantapanit (1986) and National Livestock and Meat Board (Ziegler, 1977). After skinning and evisceration, the rumen was opened and the rumen wall was inspected for ulcers and scaring. Carcass weight was determined directly after slaughtering to calculate warm carcass dressing percentage. The carcasses were separated into lean

meat, fat, bone and skin and the amounts recorded (Kantapanit, 1986). Hide weight, visceral weight, carcass composition and carcass percentage were also recorded.

Taste panelists and data collection on some beef eating qualities

Well experience taste panelists were invited for sensory evaluation. Sensory evaluation and determining of some beef eating qualities were done at Animal Produce Research and Development Center.

Data collection on some beef eating qualities

Loin samples (*Longissimus dorsi* muscle; LD) from both the right and left of each carcass were collected and chilled under 3 °C for 7 days, then kept frozen waiting further analysis of the eating quality, appearance and tenderness. A study on some beef eating qualities was done at the Animal Produce Research and Development Center. Beef eating qualities, appearance and tenderness were determined and analyzed as follow.

1. Carcass percentage (Cole *et al.*, 1968, Kantapanit, 1986) is calculated by

$$\text{Carcass percentage} = \frac{\text{Carcass weight}}{\text{Slaughtering weight}} \times 100$$
2. Loin eye area (cm².) was measured at the area of the rib eye muscle (*Longissimus dorsi* muscle) between 12th and 13th rib by using semi transparency paper and/or real time ultrasound (Pie Medical 100 Falco, U.S.A.)(Kantapanit,1986; Sretthakul and Opasattanakij, 2005; Gresham, 2001; Smith *et al.*, 2001)
3. Marbling (Score from 1 to 5; 1= no marbling and 5 = highest marbling) was measured at the rib interface of the rib eye muscle (*Longissimus dorsi* muscle) between 12th and 13th rib (National Bureau of Agricultural Commodity and Food Standards, 2005)
4. Fat Thickness (Rib Fat) (cm.) External fat thickness was measured at the 12th / 13th rib interface, perpendicular to the outside surface of the carcass at a point $\frac{3}{4}$ of the length of the rib eye from its chine-bone end. (Kantapanit, 1986; Smith *et al.*, 2001).
5. Meat color was determined by using Subjective color score which divide into 7 score (1= pale pink, 2= soft pink, 3= pink, 4= light red, 5= red, 6= medium dark red and 7= dark red) (Japan Meat Grading Association, 1990; Smith *et al.*, 2001). Meat color which consumers prefer are range from soft pink to red color (from 2 to 4)
6. Fat color was determined by using Subjective color score which divided into 7 score (Japan Meat Grading Association, 1990).

7. Tenderness (shear force; kg.) was measured by using Warner Bratzler Shear device (Challion; G-H ELEC Co. Ltd., U.S.A.) (Kantapanit, 1986). Tenderness was measured by sampling 1 in. thick rib eye muscle and roasting it at 148.5 °C until the center of the rib eye muscle is 70 °C. After cool down, the muscle was sampled by using a core (1.27 cm. of radius) cut along the muscle fiber. The meat samples were put into the triangle hole of the Warner Bratzler Shear device and the device run. The data was recorded from scale and the average calculated.

8. Sensory evaluation. Sensory evaluation is determined by using the rib eye muscle which was chilled for 7 days and roasted until the center of the rib eye muscle was 70 °C. After cool down, the meat was cut into pieces at 1 cm³. within the same muscle fiber. Tenderness, Juiciness, Meat Flavor and Overall Satisfaction were determined by taste panelists and are divided into 5 levels (Larmond, 1970; Kantapanit, 1986). Step of sensory evaluation are as follow.

1. Rinse with pure water.
2. Taste the first meat sample.
3. Evaluate and record the data.
4. Taste little piece of fruit.
5. Rinse with pure water.
6. Replete from 1-5 until all of the meat samples are determined.

Statistical analysis

All data was subjected to analysis of variance using the Completely Randomized Design (CRD) (SAS, 2003; Chantalakkana, 2006) to determine the effect of treatment diets on the various parameters studied. When significant F-values for treatment effect were found, then differences among means were compared by the Duncan's Multiple Range Test.

Experimental Station

1. Buffalo and Beef Production Research and Development Center, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom.

2. Animal Nutrition Research and Development Center, Kasetsart University, Kamphaeng Saen Campus.

3. Department of Animal Science, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Kamphaeng Saen Campus.

4. Animal hospital laboratory, Faculty of Veterinary Medicine, Kasetsart University, Kamphaeng Saen Campus.

5. Animal Produce Research and Development Center, Suwanvajokkasikit Animal Production Research and Development Institute, Kasetsart University, Kamphaeng Saen Campus.

6. Physiology laboratory of the Department of Animal Science, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Kamphaeng Saen Campus.

7. Local slaughter house at Ratchaburi Province.

Experimental period

14 February – 15 July 2006

Project V. Effects of cassava leaf meal in concentrate on feeding performance, economic return, carcass composition and some beef eating qualities of feedlot cattle

Materials

1. Ten Brahman-native crossbred young bulls at an average age of 2 years and initial weight of 273.7 ± 11.04 kg.

2. Individual 4×4 m² feeding stalls.

3. The control concentrate (CTRL) used conventional protein sources. The other treatment was concentrate in which conventional protein sources were replaced by dried cassava leaf meal (Table 18).

4. The other materials and equipments were as indicated in the fourth research project (follow 4 – 19).

Methods

Experimental animals

Ten Brahman-native crossbred young bulls at an average age of 2 years and initial weight of 273.7 ± 11.04 kg. were employed. They were treated for internal and external parasites with Ivomex-F intramuscularly, vaccinated against Foot and Mouth Disease (FMD) and were kept individually in feeding stalls where feed and water was provided. They were assigned using stratified random sampling to one of two treatment diets such that there were five animals per feed treatment. Each animal was fed with the treatment diet for two weeks before the experiment started.

Table 18 Feed composition of the experimental concentrate (III.)

Ingredient (kg.)	CTRL	CLM
Cassava chips	41.55	46.6
Soyhulls	5	-
Cocohulls	3	-
Leucaena leave meal	12	-
Cassava leave meal	-	15
Rice bran	12	12
Corn	12	12
Molasses	8	8
Urea	1.75	1.9
Zeolite	2.0	2.0
Salt	1.0	1.0
Dicalcium phosphate	1.0	1.0
Premix (Trace Mineral)	0.6	0.6
Sulphur	0.1	0.1
Total	100	100

Experimental design

The animals were randomly divided into 2 groups of 5 animals each and feedlot cattle were randomly allotted to receive one of the two treatment diets according to a Completely Randomized Design (CRD) (SAS, 2003; Chantalakkana, 2006).

Treatment diets

The feeding period was 150 days. The control concentrates (CTRL) consisted conventional protein sources used as a protein source. CTRL and treatment diets were fed to the animals *ad libitum* and supplemented with 3 kg. of para grass (*Brachiaria mutica*) daily. The other treatment was concentrate in which conventional protein sources were replaced by dried cassava leaf meal and were assigned as treatment diet (CLM) (Table 18). Diets were formulated to contain the same level of crude protein (14%) to satisfy the requirements for feedlot cattle for 1- 1.4 kg. /day of weight gain (Kearl, 1982).

Ingredients in the experimental diets consisted of cassava chips, soyhulls, cocohulls, lucaena leaf meal, cassava leaf meal, corn meal, rice bran, molasses, urea, salt, dicalcium phosphate, Zeolite, mineral premix and sulfur (Table 18).

Feeding

A 14-day adaptation period preceded the growth studies. During the adjustment period the diets were gradually introduced to the animals by reducing the level of roughage (para grass) and feeding more treatment diet every second day. They were put on the experimental diets fully in the third week and fed *ad libitum* daily at 08:00, 12.00 and 18.00 hours and supplement with 3 kg. of para grass to maintain the rumen function of the experimental animals. The experimental diets and grass were fed in the same feeding trough. Each animal had access to a mineral-vitamin lick and water at all times.

Data collection

Data was collected for 150 days starting from the third week. All data collected was indicated in the fourth research project.

Other methods

The digestibility studies, economic analysis, chemical analysis, slaughtering and carcass measurement, taste panelists and data collection on some beef eating qualities were indicated in the fourth research project.

Statistical analysis

All data were subjected to variance analysis using the Completely Randomized Design (CRD) (SAS, 2003; Chantalakkana, 2006) to determine the effect of treatment diets on the various parameters studied. When significant F-values for treatment effect were found, then differences among means were compared by the Duncan's Multiple Range Test.

Experimental Station

The experiment stations were as same as the fourth research project.

Experimental period

14 February – 30 July 2006

Project VI. Farmers' adoption and comments on using of cassava pulp and leaf meal as cattle feed

Materials

1. The objective farmers were the farmers who formulated and produced the cattle feed used in their farms from every part of Thailand.
2. Data collecting was done through the questionnaires by direct interview.
3. Digital camera used for recording the image.

Methods

Objective farmers

The objective farmers were the farmers who formulated and perform on farm feed mixing to obtain the records of using cassava pulp and cassava leave as cattle feed in the area. Most of them have undertaken the training course on the beef production, feedlot production, feed and formulation, herd and health management and etc. done by the Buffalo and Beef Production Research and Development Center, Animal Nutrition Research and Development Center, Beef Cattle Breeders Association of Thailand, Kamphaeng Saen Beef Breeders Association and KU Kamphaeng Saen Campus Beef Producer Cooperative Ltd. Some of the farmers educated directly in the field of agriculture or livestock production. Therefore, they all have enough knowledge on the use of cassava pulp and leaves for feeding the cattle. There were 54 farmers from several parts of Thailand involved in this program and were willing to fill up the questionnaires of the project.

Transferring the knowledge of using cassava pulp and leaves

Results from the earlier research were transferred to the objective farmers via the training course, seminars, meetings, beef expositions, documents, internet, consulting and etc.

Data collection

Data was collected from 54 farmers represented from every part of Thailand who formulated and produced the cattle feed used in their farms and had enough know-how of using cassava pulp and leaves. Ten percent of the objective farmers were randomly selected to pretest the questionnaire. The former questionnaire was adjusted and adapted until the confusion was settled. Data collecting was done through the questionnaires by direct interview, telephone or sent to the farmers by

mail. In case of any questions, the farmers could contact the researcher by telephone or e-mail.

Statistical analysis

Statistical analysis of the data was done with the basic statistical analysis of total number, average, percentage and range. In conclusion, the data was finally analyzed in terms of description (Chantalakkana, 2006).

Experimental period

September 2007 – February 2008

RESULTS AND DISCUSSION

Project I. Observation on the general information of cassava pulp produced and cassava pulp and leaf meal used as cattle feed in the central part of Thailand

Results and discussion

General information of the cassava starch factories

General information of the objective factories was received by direct interviewing the owners, directors, factory's managers and the private sectors that concerned in the cassava by-product business. These composed of four cassava starch factories who supplied cassava pulp as cattle feed to the farmers in this area. Due to the request, researcher was not allowed to disclose the name and company. Every factory was operated for more than ten years. It was found that around 30-35% of cassava pulp was produced (at 75 - 80 % of moisture) or 7-10% of dried cassava pulp. The input and output ratio of fresh root and starch was average 4 - 4.4:1 while fresh root and wet pulp was 3.2:1. Wet cassava pulp were produced approximately 0.112, 0.058, 0.096 and 0.09 million tons/year or dried pulp of 0.025, 0.013, 0.021 and 0.018 million tons/year from factory No.1, 2, 3 and 4, respectively. The ratio of cassava pulp held by the factory and directly sold to the farmers were 50:50, 40:60, 50:50 and 100:0 in factory No.1, 2, 3 and 4, respectively. Incase of cassava pulp held by the factory, wet and dried pulp was sold in bulk to the pellet and cassava chips producers. Wet pulp from factory No.1 was needed by the farmers and supplied mainly to the dairy cattle while wet pulp from factory No. 2 and 3 was supplied to the beef cattle. Few of wet and dried pulp were utilized in aquacultures and biogas. Factory No.4 sold most of the wet pulp only to the cassava chips producers who supplied fresh root. The wet pulp supplied to cassava chips and pellet producers was sun dried and adulterated into cassava chips and pellet. Price of wet pulp varied from 150 - 700 baht/kg. while dried pulp varied from 1.4 - 4.4 baht/kg. Other information of starch factories was shown in Table 19.

Cassava pulp

The price of wet cassava pulp depended and varied on the demand and cost of transportation which ranged from 60 to 400 baht/ton. In some locations, almost wet cassava pulp was highly demanded by the cassava chip producers for drying (sun drying) and remixing in to the cassava chips to gain more weight without concerning the quality of cassava chips. Some cassava starch factories set up the condition by selling wet cassava pulp especially to the one who sell fresh root to their factories. Dairy and feedlot farmers sometimes waited at least two days to get wet cassava pulp from the factory.

Dairy farms preferred higher technical knowledge in formulating and producing the concentrate for milking cows or heifers due to the lack of technical support from the dairy colony or cooperative. After ensiling the wet cassava pulp for a few days, they produced dairy feed in form of concentrate by mixing the pulp with other feed ingredients such as baby corn stover or fodder, rice bran, corn, cassava chips, dried brewery grain, palm oil meal, soybean meal and mineral premix. It was found from this survey that no one used dried cassava pulp as an energy source in dairy feed due to the high price (2.4 - 3.5 baht/kg.) and low nutrient composition compared to cassava chips. Dairy farmers refused of drying wet cassava pulp because of time and labour cost. However, when the price of cassava chips was higher than 5.0 - 6.0 baht/kg and dried cassava pulp was produced as feed ingredient, dairy farmers accepted to use dried cassava pulp. The reasons that the dairy farmers worry was the variable price of dried cassava pulp and the continuously supply in the long term.

Table 19 General information of starch factories at the central part of Thailand

Items \ Factory	1	2	3	4
Years of operation (years)	35	15	12	18
Fresh root/yr. (1000 tons/yrs.)	350	150 - 200	300	225-250
Product (1000 tons/yrs.)	75 ^{1/}	30 - 40 ^{1/}	70 ^{1/}	45-60
By-product: wet pulp (1000 tons/yrs.)	112	45 - 70	96	90
By-product: dried pulp (1000 tons/yrs.)	25	10 - 15	21	-
(1) Factory: farmer (pulp)	50:50	40:60	50:50	95:5
(2) Factory: farmer (purpose)	PP ^{2/} :AF ^{5/}	CPP ^{3/} :AF ^{5/}	CPP ^{3/} :AF ^{5/}	CCP ^{4/} :AF ^{5/}
Animal feed (dairy: beef: others)	80:15:5	30:60:10	20:70:10	10:70:20
Price (wet pulp) baht/ton	320	500	300	400
	(200-400)	(200-600)	(150-400)	(200-700)
Price (dried pulp) baht/kg.	1.8	1.5	-	-
	(1.6 - 4.4)	(1.4 - 4.2)		
Factory's pulp drying process	Yes	Yes	No	No
Method of pulp drying	SD ^{6/}	SD ^{6/} + HAI ^{7/}	No	No
Condition	No	No	No	Yes
Quota owner	No	No	No	> 20
	(may be)			(CCP ^{4/})
Queue for pulp loading	Yes	No	No	Yes
	(1-2 days)			

^{1/} Cassava starch, ^{2/} PP = Sell directly to the cassava pellet producers and exporters

^{3/} CPP = Sell directly to the cassava chip and pellet producers and exporters

^{4/} CCP = Sell directly to the cassava chip producers, ^{5/}AF = Animal feed,

^{6/} Sun dried,

^{7/} Hot air instrument

In feedlot production, especially the local quality, farmers accepted to use wet cassava pulp as feed supplement together with roughage such as fresh grass, rice

straw, corn stover, pineapple waste and others. Feedlot cattle received concentrate as the main source of nutrient and this survey found no feedlot producer who used dried cassava pulp as a feed ingredient. As same as the dairy producers, feedlot producers refused of drying wet cassava pulp because of time, labour cost, space and unappropriate method for feedlot production. Feedlot farmers practiced themselves to use wet cassava pulp from learning by doing and found that using the pulp as feed supplement was the right method. They had no experience or technical knowledge in formulating and producing the concentrate therefore dried cassava pulp was unnecessary to be used. However, when the price of cassava chips was higher than 5.0 - 6.0 baht/kg and dried cassava pulp was produced as a feed ingredient with no problem of supplying, feedlot farmers were willing to use it. Transferring the technical knowledge was necessary to this point. Technical support in term of training course could help them a lot.

People who lived near the cassava starch factory had new additional supplemented incomes by drying cassava pulp and selling it directly or indirectly to the dairy and feedlot producers. Pushing them to form groups of the rural producers is very necessary in the future.

Cassava leaf meal

In planting areas, cassava leaves were always thrown away during the harvesting of the cassava roots while many farmers had the negative experience of loosing the cattle from grazing on cassava leaves and tops due to the toxic cyanide content. Local feedlot and dairy producers had no idea and did not paying attention to using cassava leaf meal in concentrate. The price of other protein sources was acceptable and they didn't have enough confidence in using cassava leaves as a protein source. On the other hand, many farms did not locate in cassava planting areas where supplying dried cassava leaves as a protein source was impossible. People in the cassava planting areas have new supplemented incomes by drying cassava leaves or ensiled cassava leaves and selling it directly or indirectly to the dairy and feedlot producers. Pushing them to form groups of the rural producers is very necessary in the future for solving the problem on supplying cassava leaf meal or ensiled cassava leaf meal to the dairy and feedlot producers.

Cassava peel

Cassava peel was the waste product from cassava starch factories which came from two steps of preparing. Cassava roots were first piled up on the ground, then put into a hopper, and transferred to a conveyer belt where the woody ends of the roots were cut off by workers. The roots were then passed to a sieve to separate loose peels, sand and any adhering dirt. Second, the roots were washed in a root washer. Washing water from a washer containing some loose peels (washed peel) was passed to a rotary screen a perforate cylindrical tank with a spiral part driving the retained washed peel

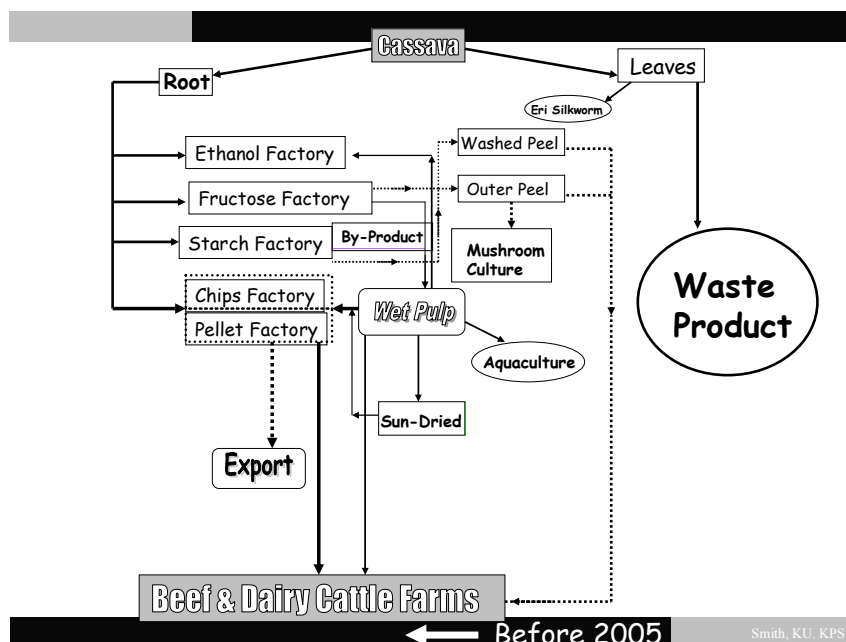


Figure 9 The using of cassava pulp and leaves in Thailand before 2005

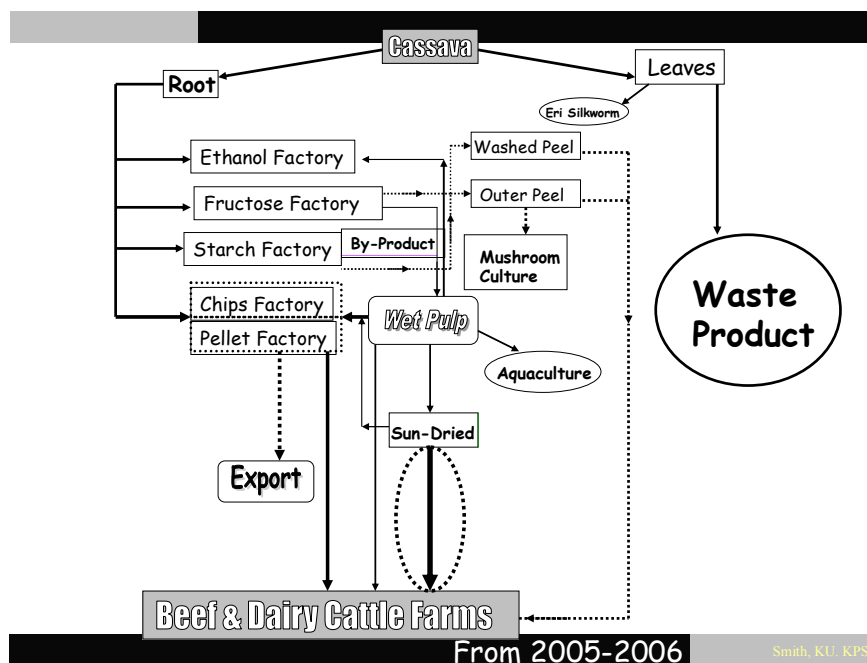


Figure 10 The using of cassava pulp and leaves in Thailand from 2005 – 2006

to an outlet (TTSA, 2008a). The inner part of the peel (washed peel) represents about 8.5 % (www.foodmarketexchange.com, 2008) of the weight of the whole root. Price of peel depended on the demanding and cost of transportation which ranged from 100 to 150 baht/ton of loose peel and 200 – 300 baht/ton of wash peel. Washed peel was mostly fed to both dairy and beef cattle as a feed supplement especially in the dry season. While loose peel was mostly used for mushroom culture, especially in Ratchaburi province.

It was found from this observation that dairy and feedlot producers used only wet cassava pulp while dried cassava pulp and leaves were neglected. Drying wet cassava pulp and leaves need more time, labour cost and space and is not appropriate method for the production system. On the other hand, many farms did not located near the cassava starch factory or cassava planting area so continuously supplying both dried cassava pulp and dried cassava leaves in long term were impossible. Transferring the technical knowledge was necessary for them. Also encouragement to formulate and produce the cattle feed themselves by using dried cassava pulp and leaves to reduce the production cost were needed. Technical support in terms of training courses could help them a lot. In the long term supplying and pushing some people who live near the starch factory or cassava planting area to produce both dried cassava pulp and leaves is necessary.

Project II. Preliminary evaluation on various methods of using ensiled cassava pulp as main energy source for feedlot cattle

Results and discussion

Chemical composition of the experimental feeds

Proximate analysis was done to determine chemical composition of the experimental feeds and found that DM were 21.43, 21.14, 21.23% and OM were 97.17, 93.82 and 90.28% of ECP, ECP2 and ECP3, respectively. The other chemical composition were CP of 1.66, 4.26 and 5.44%, CF of 12.73, 20.88 and 22.83%, Ash of 2.83, 6.18 and 9.72% for ECP, ECP2 and ECP3, respectively. DM, OM, CP, CF and Ash of leucaena leaf meal (LM) which supplemented to the control group (1 kg./h./d.) were 89.93, 88.70, 13.24, 18.52 and 11.30, respectively (Table 20).

Table 20 Chemical composition of the experimental feeds

Item (% of DM)	ECP ^{1/}	ECP2 ^{2/}	ECP3 ^{3/}	LM ^{4/}
Dry matter	21.43	21.14	21.23	89.93
Organic matter	97.17	93.82	90.28	88.70
Crude protein	1.66	4.26	5.44	13.24
Crude fiber	12.73	20.88	22.83	18.52
Ash	2.83	6.18	9.72	11.30
Calcium	0.93	0.82	1.04	1.94
Total phosphorus	0.03	0.08	0.07	0.36

^{1/} ECP = Ensiled cassava pulp, ^{2/} ECP2 = ECP+ Baby Corn Stover

^{3/} ECP3 = ECP + Baby Corn Stover + Leucaena leave meal + Sugarcane bagasse,

^{4/} LM = Leucaena leaf meal

Feedlot performances

No significant difference ($P > 0.05$) was observed between initial weight (313.80, 314.40 and 310.40 kg.), final weight (277.10, 285.20 and 272.80 kg.), weight gain (-36.80, -29.40 and -37.6 kg.), ADG (-0.35, -0.28 and -0.36 kg./day), FCR (-9.91, -12.80 and -1.98), intake/day (11.28, 13.76 and 13.93 kg./day), DM intake/day (2.93, 2.78 and 2.99 kg./day), DM intake %BW (1.06, 1.02 and 1.09 %), DM intake/day/kg.body wt.^{0.75} (41.70, 39.88 and 42.78 g./day/kg.^{0.75}) of the ECP1, ECP2 and ECP3 respectively (Table 21). Crude protein intake/day (152.70, 118.55 and 162.40 g./day) was significantly different ($P < 0.01$) between the cattle fed with ECP1, ECP2 and ECP3 respectively. As compared to the requirement of the crossbred young bull (Devendra, 1981), it was found that all of the experimental feedlot cattle received not enough DM intake and crude protein to fit the requirement.

Table 21 Effects of ECP on feeding performance and feed cost of feedlot cattle

Feedlot performance	ECP1	ECP2	ECP3	SEM	P
No. of animals (heads)	5	5	5	-	-
Initial wt. (kg.)	313.80	314.40	310.40	-	-
Feeding period (day)	105	105	105	-	-
Final wt. (kg.)	277.10	285.20	272.80	6.89	0.79
Wt. gain (kg.)	-36.8	-29.4	-37.6	7.43	0.89
ADG (kg./day)	-0.35	-0.28	-0.36	0.07	0.89
FCR	-9.91	-12.28	-1.98	2.65	0.27
DM intake					
kg. d ⁻¹ (for Maintenance) ^{2/}	5.0	5.0	5.0	-	-
kg. d ⁻¹	2.93	2.78	2.99	0.13	0.82
%BW d ⁻¹ (for Maintenance) ^{2/}	1.7	1.7	1.7	-	-
%BW d ⁻¹	1.06	1.02	1.09	0.03	0.68
g./BW ^{0.75}	41.70	39.88	42.78	1.22	0.65
CP. Intake/day (g. d ⁻¹)	152.70 ^a	118.55 ^b	162.40 ^a	7.67	0.3
CP. Intake/day (g. d ⁻¹) (for Maintenance) ^{2/}	385	385	385	-	-
Feed cost (baht/kg.)	0.41	0.26	0.27	-	-
Feed cost/day (baht)	4.62	3.60	3.77	-	-
Total feed cost/head (baht)	485.60	357.65	394.92	-	-
Palatability ^{1/}	2.98	3.08	3.15	0.08	0.15

^{1/} 4 = excellence, 3 = good, 2 = fair, 1 = poor

^{2/} **Source:** Devendra (1981)

Production cost

Feed cost (0.41, 0.26 and 0.27 baht/kg.), feed cost/day (4.62, 3.60 and 3.77 baht/day) total feed cost (485.60, 357.65 and 394.92 baht) and palatability (2.98, 3.08 and 3.15) were not significantly different ($P > 0.05$) for the ECP1, ECP2 and ECP3, respectively (Table 21).

As a result, It was found that the body weight of the experimental feedlot cattle declined even though the treatment diets were fed *ad libitum* to the animals. DM intake/day or DM intake %BW of the animal were lower than the requirement. Devendra (1981) reviewed that the crossbred young bull (*Bos indicus*) at 300 kg. of

body weight required DM intake of 5 kg./day or at 1.7% BW for maintenance. However, DM intake of the experimental cattle were 2.93, 2.78 and 2.99 kg./day or 1.06, 1.02 and 1.09 % BW. for the ECP1, ECP2 and ECP3, respectively.

The requirement of the crude protein for maintenance was 358 g./day while CP intake of the experimental cattle were only 152.70, 118.55 and 162.40 g./day for ECP1, ECP2 and ECP3, respectively. The result showed that the experimental cattle received not enough nutrients to fit the need for requirement. Skunmun *et al.* (2004) reported that Kamphaeng Saen feedlot cattle fed with ensiled cassava pulp and grass (para grass; *Brachiaria mutica*) *ad libitum* and supplemented with 2 kg./day of palm oil meal or sunflower meal gained more weight of 0.3 kg./day. Skunmun *et al.* (2005) reported that supplementation of ensiled cassava pulp and leucaena leaves to beef cattle fed with low quality grass as basal diet could improve production performances and cost of on-farm beef production.

The result from this experimental showed that the ensiled cassava pulp should not be used as the main feedlot feed due to high moisture content which resulted in lower DM intake than requirement. In conclusion, it should be used as follow:

1. It is better to use ECP as a feed supplement (Skunmun *et al.*, 2005).
2. ECP can be used as the main feed for breeding cows and supplement with high quality roughage, protein source and mineral-vitamin lick.
3. Mixing small amount of wet cassava pulp to the silage will improve the quality.
4. Mixing with concentrate as a complete feed is more suitable for feedlot cattle and should not be fed exceedingly to the cattle. The refusals of the complete feed will easily turn putrid due to the high moisture content.
5. Three to five daily feeding times will increase feed intake and avoid the refusal of the complete feed.
6. Prolonging of ensiling wet cassava pulp by 1-2 weeks before feeding to the animals can reduce the moisture content and improve the feed intake.
7. Dried (sun drying) cassava pulp have more potential to be used as feed ingredient or stocking for feedlot diet. However, more research on using dried cassava pulp as feed ingredient (energy source) is needed to confirm the concept.
8. Feedlot producers in the surrounding area of the cassava starch factories have more potential to reduce the production cost by using cassava pulp for feedlot cattle by following the 1-6 methods.

Project III. Effects of replacing cassava chip with dried cassava pulp in concentrate on feeding performance, carcass quality and economic return of feedlot cattle

Results and discussion

Chemical composition of the experimental feeds

Proximate analysis was done to determine chemical composition of the experimental feeds and found that DM were 91.01, 92.54, 92.56, 91.22% and OM were 91.99, 92.66, 94.45 and 94.14% of CTRL, DCP10, DCP20 and DCP30, respectively. The other chemical composition were CP of 14.56, 14.05, 13.99 and 13.50%, TDN (calculated) of 79.40, 78.80, 76.90 and 75.20%, CF of 8.20, 8.65, 9.51 and 10.18%, Ash of 8.01, 7.34, 5.55 and 5.86% for CTRL, DCP10, DCP20 and DCP30, respectively (Table 22). Chemical composition of para grass (*Brachiaria mutica*) which supplemented to the experimental animals (3 kg./h./d.) were shown in Table 16.

Table 22 Chemical composition of the experimental concentrate (I.)

Chemical composition	CTRL	DCP10	DCP20	DCP30
Crude Protein (calculated)	14.06	13.90	14.18	13.99
Crude Protein (Prox. analysis)	14.56	14.05	13.99	13.50
TDN (calculated)	79.40	78.80	76.90	75.20
Crude fiber	8.20	8.65	9.51	10.18
EE	3.05	2.87	2.61	2.5
DM	91.01	92.54	92.56	91.22
OM	91.99	92.66	94.45	94.14
Ash	8.01	7.34	5.55	5.86
Calcium	0.91	0.87	0.74	0.83
Phosphorus	0.31	0.34	0.30	0.29
Bulk density (g./ lit)	564.50	541.5.20	518.60	498.60
Price (baht / kg.)	5.54	5.34	5.13	4.91

Feedlot performances

No significant difference was observed on initial weight (296.02, 287.76, 294.18 and 295.94 kg.), final weight (450.12, 434.00, 445.50 and 425.50 kg.), weight gain (150.30, 146.24, 151.34 and 129.60 kg.), ADG (1.25, 1.25, 1.29 and 1.09 kg./day) and FCR (6.39, 6.91, 7.01 and 7.91) of the CTRL, DCP10, DCP20 and DCP30 respectively (Table 23). No significant difference was observed on DM intake/day (7.99, 8.37, 8.67 and 8.39 kg./day), DM intake (%BW) (2.15, 2.32, 2.34 and 2.32), DM intake/day/kg.body wt.^{0.75} (104.17, 101.07, 102.50 and 101.32 g.) and palatability (3.20, 3.46, 3.58 and 3.2) of the CTRL, DCP10, DCP20 and DCP30

respectively. Feed cost (5.54, 5.34, 5.13 and 4.91 baht/kg.), total feed cost (5,058.30, 4,465.39, 4,494.83 and 4,171.83 baht), feed cost/day (42.15, 37.21, 37.45 and 34.77 baht/day) and feed cost/kg. of gain (33.65, 30.74, 30.24 and 33.02 baht/kg.) were not significantly different ($P>0.05$) for the CTRL, DCP10, DCP20 and DCP30, respectively (Table 23).

Table 23 Effects of DCP in concentrate on feeding performance and feed cost of feedlot cattle

Feedlot Performance	CTRL	DCP10	DCP20	DCP30	SEM	P
No. of animal	5	5	5	5	-	-
Initial wt. (kg.)	296.02	287.76	294.18	295.94	-	-
Feeding period (day)	120	120	120	120	-	-
Final wt. (kg.)	450.12	434.00	445.50	425.50	6.77	0.69
Wt. gain (kg.)	150.30	146.24	151.34	129.60	5.47	0.50
ADG (kg./day)	1.25	1.25	1.29	1.09	0.05	0.43
FCR	6.39	6.91	7.01	7.91	0.23	0.09
Total DM intake (kg.)	958.29	1,003.7	1,040.8	1,007.1	22.62	0.68
DM intake (% of body wt.)	2.15	2.32	2.34	2.32	0.03	0.17
DM intake/day (kg.)	7.99	8.37	8.67	8.39	0.19	0.68
DM intake/day/kg.body wt. ^{0.75} (g.)	104.17	101.07	102.50	101.32	1.69	0.89
Digestibility coefficient, %						
CP	63.51	69.92	61.69	61.08	1.72	0.31
OM	69.25	67.92	82.37	79.05	2.53	0.11
DM	66.52	70.41	69.93	70.21	1.04	0.53
CF	53.71 ^a	40.56 ^b	48.37 ^{ab}	49.83 ^a	1.67	0.04
Palatability ^{1/}	3.20	3.46	3.58	3.20	0.07	0.08
Feed cost (baht/kg.)	5.54	5.34	5.13	4.91	-	-
Total feed cost (baht)	5,058.3	4465.39	4494.83	4171.83	126.2	0.08
Feed cost / day (baht)	42.15	37.21	37.45	34.77	1.05	0.08
Feed cost/kg.of gain (baht)	33.65	30.74	30.24	33.02	3.85	0.44

^{a,b} Mean within rows with different superscripts differ ($P<0.05$),

^{1/} 4 = excellence, 3 = good, 2 = fair, 1 = poor

Results from this research were consistent with Napisirth *et al.* (2005) who studied the utilization of energy feed sources and cassava starch industry by-products (pulp) in beef cattle (Brahman crossbred female) and found that voluntary feed intake of dry matter of the animals offered rations containing cassava pulp was higher than

the rations containing cassava chips ($p < 0.05$) However, average daily gain was not significantly different ($p > 0.05$).

Digestibility coefficient

Feces samples of the feedlot cattle were collected to analyze and determine the digestibility coefficient at 1 and 3 months of the experiment. Within treatment diets, digestion coefficient of CP (63.51, 69.92, 61.69 and 61.08 %), OM (69.25, 67.92, 82.37 and 79.05 %) DM (66.52, 70.41, 69.93 and 70.21%) appeared to be the same with no significant difference ($P > 0.05$) among the cattle fed with CTRL, DCP50 and DCP100, respectively. It was found that the digestibility coefficient of CF of the feedlot cattle fed with CTRL was higher than DCP30, DCP20 and DCP10 (53.71, 49.83, 48.37 and 40.56 %), respectively with significant difference ($P < 0.05$). Results from this research were consistent with Napasirth *et al.* (2005) who studied the utilization of energy feed sources and cassava starch industry by-products (pulp) in beef cattle (Brahman crossbred female) and found that nutrients digestibility, ruminal fermentation end-products, blood metabolites and rate of passage were not significantly different ($p > 0.05$).

Table 24 Effects of DCP in concentrate on carcass quality and economic return of feedlot cattle

Carcass quality and profit	CTRL	DCP10	DCP20	DCP30	SEM	P
No. of animals	5	5	5	-	-	
Live wt. (kg.)	446.32	428.30	450.20	414.90	7.41	0.32
Carcass wt. (kg.)	245.17	243.30	249.10	237.70	3.56	0.76
Dressing (%)	56.43	56.90	55.40	57.30	0.38	0.32
Lean wt. (kg.)	204.50	198.00	198.20	190.90	2.96	0.48
Lean (%)	45.32	46.36	44.07	45.72	0.50	0.46
Total feed cost (baht)	5,058	4,466	4,495	4,172	-	-
Cost of feedlot cattle (baht)	14,000	14,000	14,000	14,000	-	-
Other production cost (baht)	1,030	1,030	1,030	1,030	-	-
Total production cost (baht)	20,088	19,496	19,524	19,202	-	-
Total lean cost (baht) : 105 baht/kg.	21,473	20,790	20,811	20,045	-	-
Profit / head (baht)	1,384.6	1,294.6	1287	842.7	-	-
% Profit	6.84	6.62	6.42	4.36	1.04	0.85

Carcass quality and economic return of the feedlot cattle

After the feeding trial, all feedlot cattle were sent to the slaughter house for carcass quality evaluation. It was found that live weight (446.32, 428.3, 450.20 and 414.90 kg.), carcass weight (245.17, 243.30, 249.10 and 237.70 kg.), carcass percentage (56.43, 56.90, 55.4 and 57.3%), lean weight (204.50, 198.00, 198.20 and 190.90 kg.) and lean percentage (45.32, 46.36, 44.07 and 45.72%) had no significant difference ($P < 0.05$) of the cattle fed with CTRL, DCP10, DCP20 and DCP30, respectively. The total feed cost and total production cost of the cattle fed with CTRL was higher than DCP10 and DCP20 while DCP30 was the cheapest (Table 24).

The total feed cost were 5,058.30, 4,465.39, 4,494.83 and 4,171.83 baht and total production cost were 20,088.30, 19,495.39, 19,524.01 and 19,201.83 baht of the cattle fed with CTRL, DCP10, DCP20 and DCP30, respectively. The production cost of the experimental feedlot cattle was studied to evaluate the economic return. The feedlot cattle fed with CTRL had the highest total lean cost than DCP10, DCP20 and DCP30 (21,472.90, 20,790.00, 20,811.00 and 20,044.50 baht, respectively). However, the feedlot cattle fed with DCP30 still had profit when compared to CTRL, DCP10 and DCP20 of 4.36, 6.84, 6.62 and 6.42%, respectively. The result of this experiment indicated that DCP has potential to be used as an energy source in concentrate for feedlot cattle. Even though, the feedlot performance was a little bit lower but still satisfied the economic return.

Replacing cassava chip with dried cassava pulp up to 30% in concentrate didn't show any difference on feedlot performance, carcass quality and economic return of the local quality feedlot production. Although, weight gain, ADG and FCR tended to be lower at 30% of DCP but still satisfied the economic return. Dried cassava pulp still has enough potential to be use as a feed ingredient in feeding ration especially for the small farmers who raise feedlot cattle around the cassava planting area, cassava starch and cassava sweetener factories. Helping the feedlot producers to reduce the production cost is very important because of more than 90% of meat consumption in Thailand are coming from the small holders (Yimmongkol, 1990; Yimmongkol *et al.*, 2002) especially when the price of feed ingredients rise up. However, more research on replacing cassava chip with cassava pulp at higher level or as a main energy source in concentrate is need to confirm the potential use of dried cassava pulp.

Project IV. Effects of dried cassava pulp as a main source of energy in concentrate on feeding performance, carcass quality, carcass composition, some beef eating qualities and economic return of feedlot cattle

Results and discussion

Chemical composition of feedlot feed

Chemical composition of the treatment diets were analyzed and found that CP of 14.50, 13.45 and 13.77%, CF of 8.47, 10.25 and 13.06%, Ash of 9.19, 8.78 and 10.67%, EE of 3.80, 3.08 and 3.60%, NDF of 20.08, 21.92 and 26.73%, ADF of 12.48, 16.94 and 21.76%, Lignin of 3.14, 3.32 and 4.32%, Cal/g. of 4, 116.70, 4,016.77 and 4,090.05 cal. for the CTRL, DCP50 and DCP100, respectively (Table25).

Table 25 Chemical composition of the experimental concentrate (II.)

Chemical composition (% of DM)	CTRL	DCP 50	DCP 100
Crude Protein (calculated)	14.25	14.40	14.50
Crude Protein (Prox. analysis)	14.50	13.45	13.77
TDN (calculated)	79.43	75.50	71.46
Crude fiber	8.47	10.25	13.06
Ash	9.19	8.78	10.67
EE	3.80	3.08	3.60
NDF	20.08	21.92	26.73
ADF	12.48	16.94	21.76
Lignin	3.14	3.32	4.32
Cal/g.	4,116.7	4,016.77	4,090.05
Bulk density (g./ lit)	560.19	526.39	487.04
Price (baht / kg.)	4.84	4.40	4.14

Feedlot performances

No significant difference was observed on final weight (388.40, 384.80 and 379.80 kg.), weight gain (117.20, 102.00 and 104.50 kg.), ADG (0.78, 0.68 and 0.70 kg./day) and FCR (8.80, 8.67 and 9.42) of the CTRL, DCP50 and DCP100, respectively (Table26). It was found that total DM intake (997.55, 854.68 and 976.73 kg.), DM intake/day (6.65, 5.70 and 6.50 kg./d.), DM intake (% BW) (3.02, 2.56 and 2.98%) had significant difference ($P < 0.05$) of the CTRL, DCP50 and DCP100, respectively. Feed cost (4.84, 4.4 and 4.14 baht/kg.) and feed cost/kg. of gain (44.38, 39.58 and 41.54) were not significantly different ($P > 0.05$) but feed cost/day (33.58, 26.02 and 28.72 baht/day) was significantly different ($P < 0.01$) among the cattle fed with CTRL, DCP50 and DCP100, respectively (Table 26). Although, feed intake

decrease in the feedlot cattle fed with DCP50 but did not influence feedlot performances (weight gained, ADG and FCR) and was consistent with Sommart and Bunnakit (2004). However, more selective eating behavior of the feedlot cattle fed with DCP50 was observed as compared to CTRL and DCP100 as shown by the palatability score (Table 26) .

Table 26 Effects of DCP in T.M.R on feedlot performance and feed cost of feedlot cattle

Feedlot performance	CTRL	DCP 50	DCP 100	SEM	P
No. of animals	5	5	5	-	-
Initial wt. (kg.)	271.20	282.80	275.30	2.70	0.22
Final wt. (kg.)	388.40	384.80	379.80	4.80	0.80
Gain (kg.)	117.20	102.00	104.50	6.40	0.60
ADG. (kg./day)	0.78	0.68	0.70	0.04	0.60
FCR	8.80	8.67	9.42	0.35	0.70
Total DM intake (kg.)	997.55 ^a	854.68 ^b	976.73 ^a	26.8	0.039
DM intake (kg d ⁻¹)	6.65 ^a	5.70 ^b	6.50 ^a	0.18	0.04
DM intake (%BW d ⁻¹)	3.02 ^a	2.56 ^b	2.98 ^a	0.08	0.014
DM intake (g./BW ^{0.75})	85.84 ^a	72.95 ^b	84.60 ^a	2.24	0.016
Feed cost (baht/kg.)	4.84	4.40	4.14	-	-
Feed cost/day (baht)	33.58 ^A	26.02 ^B	28.72 ^B	1.15	0.006
Feed cost/kg. of gain (baht)	44.38	39.58	41.54	1.70	0.50
Palatability ^{1/}	2.80	2.50	2.60	0.72	0.14

^{A,B} Means within rows with different superscripts differ (P<0.01)

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

^{1/} 4 = excellence, 3 = good, 2 = fair, 1 = poor

Digestibility coefficient

Feces samples of the feedlot cattle were collected to analyze and determine the digestibility coefficient at 2 and 4 months of the experiment. Within treatment diets, digestion coefficient of DM (68.87, 71.86 and 70.95%) and OM (75.97, 75.72 and 77.42%) appeared to be the same with no significant difference (P>0.05) among the cattle fed with CTRL, DCP50 and DCP100, respectively. DCP100 had the highest of digestibility coefficient of CP and CF as compared to CTRL and DCP50 as same as the digestibility coefficient of NDF and ADF. The digestibility coefficient of CP (68.65, 63.5 and 72.01% for the CTRL, DCP50 and DCP100, respectively) were significantly different (P<0.01). This might be the effect of more urea put in DCP100. The digestibility coefficient of CF (49.51, 55.69 and 64.76% for the CTRL, DCP50

and DCP100, respectively) were significantly different ($P<0.01$) and were consistent to proximate analysis of CF in the treatment diet. Digestibility coefficient of NDF and ADF of DCP100 was also the best ($p<0.05$), the digestibility coefficient of NDF were 52.62, 49.84 and 60.26% and of ADF were 67.74, 64.96 and 74.14% of the CTRL, DCP50 and DCP100, respectively (Table 27), and were consistent to proximate analysis of NDF and ADF in the treatment diet (Table 25).

Table 27 Effects of DCP in concentrate on blood urea nitrogen (BUN), blood glucose, T3, ammonia nitrogen, volatile fatty acid, digestibility coefficient, pH and ecology of the rumen fluid of feedlot cattle

Item	CTRL	DCP50	DCP100	SEM	P
BUN (0hr.) (mg%)	10.12	11.20	10.68	0.23	0.15
Blood glucose (mg%)	82.58	77.77	79.53	1.70	0.54
T3 (mg%)	166.80	147.60	175.80	10.14	0.55
Rumen ammonia nitrogen (mg%)	7.08 ^b	7.84 ^a	7.98 ^a	0.12	0.015
Rumen Total VFA (mmol./l)					
Acetic acid	64.32	67.59	67.39	0.98	0.33
Propionic acid	21.35	22.12	23.87	0.59	0.21
Butyric acid	12.73 ^A	11.70 ^C	12.13 ^B	0.13	0.0002
Digestibility coefficient, %					
CP	68.65 ^A	63.50 ^B	72.01 ^A	1.25	0.008
OM	75.97	75.72	77.42	0.67	0.57
DM	68.87	71.86	70.95	1.15	0.59
CF	49.51 ^C	55.69 ^B	64.76 ^A	1.91	0.0001
NDF	52.62 ^b	49.84 ^b	60.26 ^a	1.634	0.0114
ADF	67.74 ^b	64.96 ^b	74.14 ^a	1.426	0.012
pH of rumen fluid	6.67	6.88	6.89	0.045	0.063
Protozo (Entodiniomorphs)	1.91	2.76	2.08	0.22	0.25
(x10 ⁵ cells/ml.)					
Protozoa (Holotrichia)	0.14	0.11	0.07	0.02	0.26
(x10 ⁵ cells/ml.)					
Bacteria (x10 ⁸ cells/ml.)	3.07	3.15	3.33	0.16	0.81
Fungal zoospores (x10 ⁶ cells/ml.)	0.11 ^b	0.20 ^{ab}	0.23 ^a	0.02	0.041

^{A,B} Means within rows with different superscripts differ ($P<0.01$),

^{a,b} Mean within rows with different superscripts differ ($P<0.05$)

Blood urea nitrogen, glucose and T₃

Blood urea nitrogen (BUN) indicates the protein digestibility and utilization by rumen and small intestine or the amount of urea nitrogen, a waste product of protein metabolism, in the blood. Urea is formed by the liver and carried by the blood to the kidneys for excretion. BUN in beef cattle is normally at 11.1-15.2 mg./100ml. (Byers and Moxon, 1980). Blood glucose (BG) indicated the energy level

and utilization of animal feed and normally reaches the maximum level at 4 hr. after feeding (Mahardik *et al.*, 2000). The thyroid hormones, tetraiodothyronine or thyroxine (T_4) and 3-3'-5-triiodothyronine (T_3) act on different target tissues, stimulating oxygen utilization and heat production in every cell of the body. The overall effect of these hormones are to increase the basal metabolic rate, to make more glucose available to cells, to stimulate protein synthesis, increase lipid metabolism and to stimulate cardiac and neural functions. Level of T_3 and T_4 indicate the digestibility of animal feed and are considered to be good indicators of the nutritional status of an animal (Capen and Martin, 1989; Riis and Madsen, 1985).

In case of this experiment, no significant difference was observed ($P>0.05$) on blood urea nitrogen (BUN) (10.12, 11.2 and 10.68 mg.%), blood glucose (82.58, 77.77 and 79.53 mg.%) and T_3 (Caloriegenic hormone) (166.8, 147.6 and 175.8 mg.%) of the cattle fed with CTRL, DCP50 and DCP100, respectively. However, the feedlot cattle fed with DCP 100 had the highest T_3 when compared to CTRL and DCP50 which were consistent to the total feed intake (Table 27). The results revealed that diet containing DCP replaced of cassava meal at 50% and up to 100% as energy source had BUN, blood glucose and T_3 similar to cassava chip diet.

Ammonia nitrogen, volatile fatty acids and pH of the rumen fluid

Rumen ammonia nitrogen (NH_3 -N) indicated the intake and digestibility of crude protein in ruminant feed (Hammond, 1983) and correlate to BUN (Church, 1979). Satter and Slyter (1974) reported that NH_3 -N which was suitable for development and activity of microbial rumen should be at 5-8 mg./100ml. with the minimum requirement of 5 mg./100ml. Volatile fatty acids (VFA) are produced in large amounts through ruminal fermentation and are of paramount importance in that they provide greater than 70% of the ruminant's energy supply. Virtually all of the acetic, propionic and butyric acids formed in the rumen are absorbed across the ruminal epithelium, from which they are carried by ruminal veins to the portal vein and hence through the liver. Continuous removal of VFA from the rumen is important not only for distribution, but to prevent excessive and damaging drops in pH of rumen fluid (Bowen, 1998).

Environmental conditions in the fermentation vat also can have profound effects on the microbial flora. Rumen fluid normally has a pH between 6 and 7, but may fall if large amounts of soluble carbohydrate are consumed. If pH drops to about 5.5, protozoal populations become markedly depressed due to acid intolerance. More drastic lowering of rumen pH, as can occur with grain engorgement, can destroy many species and have serious consequences to the animal (Bowen, 1998).

It was found that ammonia nitrogen content in the rumen fluid of the cattle fed with DCP 100 was higher than DCP50 and CTRL and was significantly different ($P<0.05$). The result of the ammonia nitrogen was consistent to the digestibility coefficient of CP (Table 27) and due to the higher content of urea in DCP50 and

DCP100, respectively. Ammonia nitrogen of the rumen fluid was 7.08, 7.84 and 7.98 mg% of the cattle fed with CTRL, DCP50 and DCP100, respectively. Acetic acid (64.32, 67.59 and 67.39 mmol/l) and propionic acid (21.35, 22.12 and 23.87 mmol/l) were not significantly different ($P>0.05$) while butyric acid (12.73, 11.70 and 12.13 mmol/l) was significantly different ($P<0.01$) among the cattle fed with CTRL, DCP50 and DCP100, respectively (Figure 11). The pH of rumen fluid was also studied and found no significant difference ($P>0.05$) as showed in Table 27 and Figure 12. The results revealed that diet containing DCP replaced of cassava meal at 50% and up to 100% as energy source performed the rumen pH, acetic acid and propionic acid as well as cassava chip diet.

Populations of microbial rumen

Each milliliter of rumen content contains roughly 10 to 50 billion bacteria, 1 million protozoa and variable numbers of yeasts and fungi. Fermentative microbes interact and support one another in a complex food web, with the waste products of some species serving as nutrients for other species (Bower, 1998).

Bowen (1998) reviewed that bacterial populations produce acetate, the predominant acid within the rumen. The bacteria also produce propionate, the only fermentation acid that can be converted into carbohydrates by the ruminant. Some nitrogen fixation activity also takes place in the rumen. The next abundant population of microflora is the protozoans, most are ciliates, but some flagellates such as Diplodinium, Sarcodina, etc. are also present. They digest cellulose and starch, some ferment dissolved carbohydrates. Some are predators on bacterial populations. The high diversity of microbial population in the rumen depends on the diet of the ruminant. When there is a sudden change in the diet, there is an upset of the rumen fermentation system resulting in excessive production of methane that can distend the rumen, sometimes to the extent that it compresses the lungs thus suffocating the animal. The fungal population is comparatively low and only some genera of yeasts are present. The food consumed by the ruminant goes to the rumen where there is great microbial diversity and this diversity helps in the digestion of the food consumed.

Ecology or microbial population of the rumen fluid on the replacement of cassava meal by DCP was found no significant difference on the amount of protozoa in both groups of Entodiniomorphs ($1.91, 2.76$ and 2.08×10^5 cells/ml.) and Holotrichia ($0.14, 0.11$ and 0.07×10^5 cells/ml.), bacteria ($3.07, 3.15$ and 3.33×10^8 cells/ml.) while the fungal zoospores ($0.11, 0.20$ and 0.23×10^6 cells/ml.) was significantly different ($p<0.05$) among the cattle fed with CTRL, DCP50 and DCP100, respectively (Figure 13, 14 and 15). DCP100 had the highest population of fungal zoospores as compared to DCP50 and CTRL. Orpin (1989) reported that high amount of zoospores in rumen fluid indicated the high efficiency of fiber digestion which was consistent to the digestibility coefficient of CF, NDF and ADF of this research results (Table 25 and 27). In conclusion, the results revealed that replacement

of cassava meal by DCP did not influence the population of bacteria and protozoa but affect to the population of fungal zoospores in the rumen fluid.

Carcass quality and composition

After the feeding trial, all feedlot cattle were sent to the slaughter house to study carcass quality and composition. From Table 28, carcass composition of the experimental feedlot cattle showed that slaughtering weight (393.2, 388.8 and 383.0 kg.), carcass weight (213.8, 210.8 and 204.75 kg.), carcass percentage (54.5, 54.2 and 53.5%), lean weight (170.8, 168.8 and 165.0 kg.), lean percentage (44.3, 43.5 and 43.1%), hide weight (44.81, 45.39 and 42.92), hide percentage (11.30, 11.69 and 11.36%), bone weight (52.74, 51.2 and 50.65 kg.), bone percentage (13.42, 13.19 and 13.41%), weight of abdominal fat (14.42, 12.39 and 13.08 kg.) and abdominal fat percentage (6.68, 5.86 and 6.48%) were not significantly different ($P>0.05$) among the cattle fed with CTRL, DCP50 and DCP100, respectively. Carcass qualities of the experimental feedlot cattle showed that marbling (1.2, 1.2 and 1.0), fat thickness (0.28, 0.28 and 0.24 cm.), meat color (3.4, 3.5 and 3.0), fat color (3.80, 3.75 and 4.0), total loin eye area (57.3, 55.08 and 50.81 cm²), loin eye area/100 kg. of carcass weight (26.81, 26.34 and 24.81 cm²/100 kg.) were not significantly different ($P>0.05$) among the cattle fed with CTRL, DCP50 and DCP100, respectively.

Shear force and sensory evaluation

The overall satisfaction of the consumers on beef are general appearance, colour, price and some beef eating qualities such as tenderness, juiciness, marbling, smell and taste (Kantapanit, 1986). Results from the Warner Bratzler Shear device indicated that shear force (2.26, 1.99 and 2.12 kg.), tenderness (3.42, 2.94 and 3.50), juiciness (3.40, 3.46 and 3.35), meat flavor (3.36, 3.02 and 3.20) and overall satisfaction (3.4, 2.94 and 3.41) were not significantly different ($P>0.05$) among the cattle fed with CTRL, DCP50 and DCP100 total, respectively (Table 28). The result from this experiment revealed that the use of DCP as a main energy source in concentrate did not influence beef eating qualities of the feedlot cattle.

Economic return of the feedlot cattle

The total feed cost and total production cost of the cattle fed with CTRL was higher than DCP100 while DCP50 has the lowest production cost (Table 29). The total feed costs were 5,037.5, 3,903.7 and 4,307.4 baht and total production costs were 18,667.5, 17,533.7 and 17,937.4 baht for the cattle fed with CTRL, DCP50 and DCP100, respectively. The production cost of the experimental feedlot cattle was studied to determine the economic return. The feedlot cattle fed with CTRL had the highest carcass price than DCP50 and DCP100 (19,146.80, 18,871.90 and 18,442.60 baht) due to the carcass weight. Carcass price was varied from 88 to 90 baht/kg. and depended on carcass weight. As compared to the production cost, feedlot cattle on

DCP 50 had a higher profit (10.48%) than those on CTRL (8.05%) and DCO100 (7.38%).

Table 28 Effects of DCP as a main energy source in concentrate on carcass quality, carcass composition and some beef eating qualities of the feedlot cattle

Item	CTRL	DCP50	DCP100	SEM	P
No. of animals (heads)	5	5	5	-	-
Slaughtering weight (kg.)	393.20	388.80	383.00	6.30	0.84
Carcass weight (kg.)	213.80	210.80	204.75	3.20	0.57
Dressing (%)	54.50	54.20	53.50	0.51	0.78
Lean weight (kg.)	170.80	168.80	165.00	2.90	0.76
Lean (%)	44.30	43.50	43.10	0.44	0.53
Hide (kg.)	44.81	45.39	42.96	1.37	0.78
Hide (%)	11.30	11.69	11.36	0.29	0.86
Bone (kg.)	52.74	51.20	50.65	0.82	0.59
Bone (%)	13.42	13.19	13.41	0.21	0.89
Abdominal fat (kg.)	14.42	12.39	13.08	0.51	0.27
Abdominal fat (%)	6.68	5.86	6.48	0.21	0.27
Marbling ^{1/}	1.20	1.20	1.00	0.09	0.62
Rib fat (cm.)	0.28	0.28	0.24	0.01	0.24
Meat color ^{2/}	3.40	3.50	3.00	0.41	0.90
Fat color ^{3/}	3.80	3.75	4.00	0.19	0.88
Loin eye area (cm.) ²					
- Total (cm.) ²	57.30	55.08	50.81	1.03	0.25
- Per 100 kg. of carcass weight (cm) ² /100 kg.	26.81	26.34	24.18	0.78	0.36
Shear force (kg.)	2.26	1.99	2.12	0.33	0.95
Tenderness ^{4/}	3.42	2.94	3.50	0.14	0.25
Juiciness ^{5/}	3.40	3.46	3.35	0.11	0.95
Meat flavor ^{6/}	3.36	3.02	3.20	0.08	0.26
Overall satisfaction ^{7/}	3.40	2.94	3.41	0.11	0.15

^{A,B} Means within rows with different superscripts differ (P<0.01)

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

^{1/} Marbling score from 1 to 5; 1= no marbling and 5 = highest marbling score

^{2/} Meat color score from 1-7; 1= pale pink, 2= soft pink, 3= pink, 4= light red, 5= red, 6= medium dark red and 7= dark red

^{3/} Fat color score from 1-7; 1= turbid white, 2= medium turbid white, 3= light turbid white, 4= white, 5=light pinky white, 6= medium pinky white, 7= pinky white

^{4/} Tenderness score from 1-5; 1= excellence, 2= good, 3= medium, 4= fair, 5= poor

^{5/} Juiciness score from 1-5; 1= excellence, 2= good, 3= medium, 4= fair, 5= poor

^{6/} Meat flavor score from 1-5; 1= excellence, 2= good, 3= medium, 4= fair, 5= poor

^{7/} Overall satisfaction score from 1-5; 1= excellence, 2= good, 3= medium, 4= fair, 5= poor

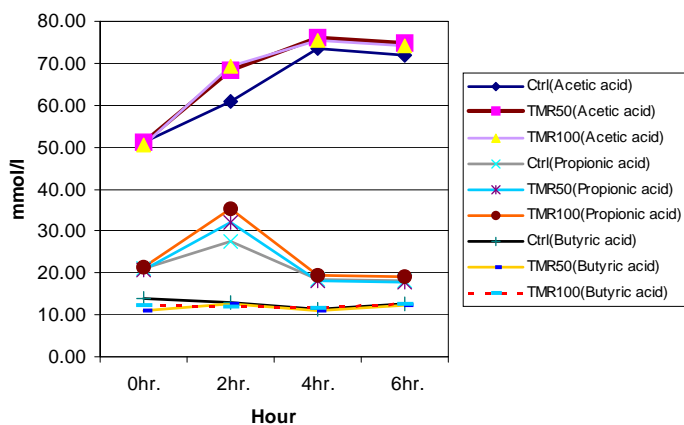


Figure 11 Effects of dried cassava pulp in concentrate on VFA of the rumen fluid

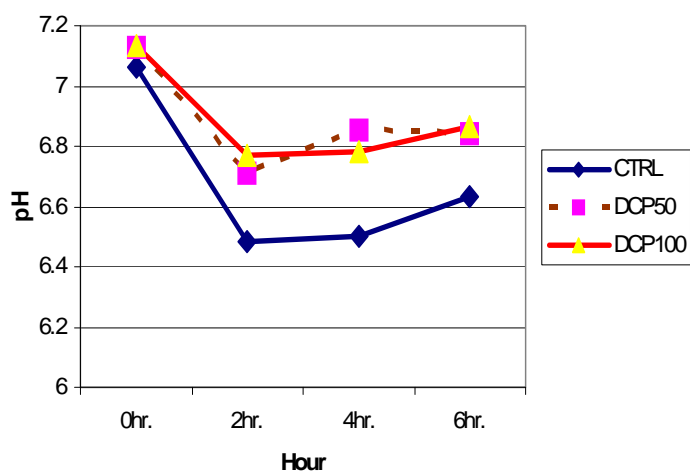


Figure 12 Effect of dried cassava pulp in concentrate on pH of the rumen fluid

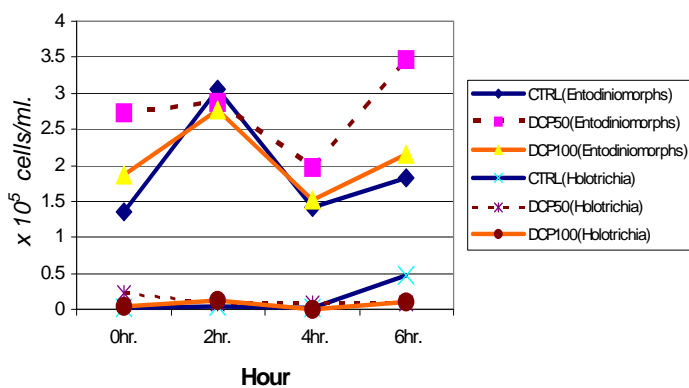


Figure 13 Effects of dried cassava pulp in concentrate on direct count of protozoa in the rumen fluid

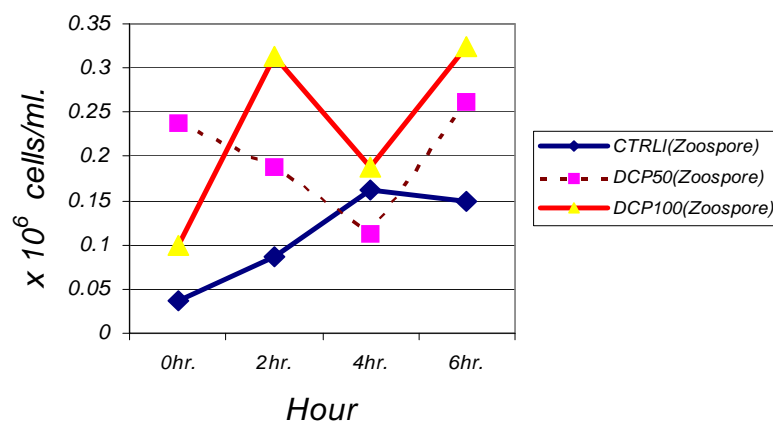


Figure 14 Effect of dried cassava pulp in concentrate on direct count of fungal zoospores in the rumen fluid

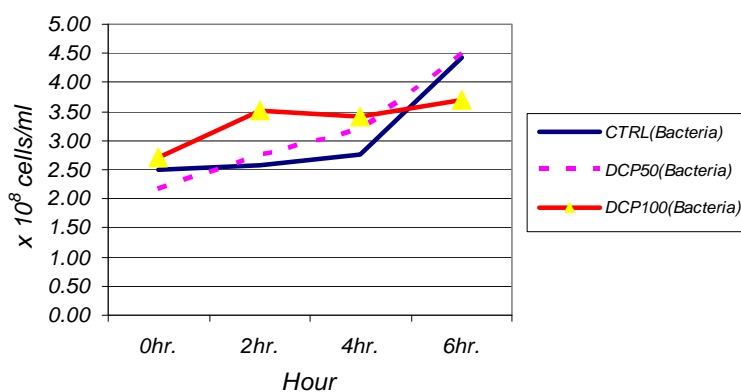


Figure 15 Effect of dried cassava pulp in concentrate on direct count of bacteria in the rumen fluid

The feedlot performances, carcass quality and carcass composition of the feedlot cattle didn't show any difference. The results revealed that diet containing DCP replaced of cassava meal at 50% and up to 100% as energy source did not influence feedlot performance, carcass weight, carcass percentage, lean weight and lean percentage. Even though ADG tended to be lower ($P= 0.60$) than cassava chip diet, DCP still had enough potential to be use as an energy source in feedlot ration especially for the small farmers who produced feedlot cattle around cassava starch and sweetener factories.

Table 29 Effects of DCP as a main energy source in concentrate on economic return of feedlot cattle

Carcass quality and profit	CTRL	DCP 50	DCP100	SEM	P
Initial wt. (kg.)	271.20	282.80	275.30	2.70	0.22
Live wt. (kg.)	393.20	388.80	383.00	6.30	0.84
Carcass wt. (kg.)	213.80	210.80	204.75	3.20	0.57
Lean wt. (kg.)	170.80	168.80	165.00	2.90	0.76
Total feed cost (baht)	5,037.50 ^A	3,903.70 ^B	4,307.40 ^B	173.12	0.006
Cost of feedlot cattle (baht)	11,661.60	12160.40	11,919.60	-	-
Cost of feedlot cattle (baht/kg.)	43	43	43	-	-
Other production cost (baht)	1,030	1,030	1,030	-	-
Total production cost (baht)	18,667.50 ^A	17,533.70 ^B	17,937.40 ^B	173.12	0.006
Carcass price (baht) ¹	19,146.80	18,871.90	18,442.60	293.80	0.67
Sale price/kg. body wt. (baht/kg.)	48.80	48.53	48.14	0.41	0.84
Profit / head (baht)	1,417.70	1,777.80	1,269.40	292.33	0.80
% Profit	8.05	10.48	7.38	1.73	0.74

¹ Carcass wt. > 190 kg. = 90 baht/kg.; Carcass wt. < 190 kg. = 88 baht/kg.

^{A,B} Means within rows with different superscripts differ (P<0.01)

^{a,b} Means within rows with different superscripts differ (P<0.05)

Sensory evaluation on some beef eating qualities didn't show any difference and confirmed the potential use of DCP. All economic return of every group of feedlot cattle was satisfied and helps saving production cost. However, this experimental period was too long (150 days) while the feedlot production for local market should not exceed than 120 days (Yimmongkol, 1990; Yimmongkol *et al.*, 2002). Compensatory growth at the early stage of feedlot help saving cost of production and also group feeding of on farm feedlot production system usually has better ADG and gain more weight due to feeding behavior (Prucasri, 1990). On the other hand, DCP as an energy source in feedlot feed for prime quality beef production can be applied especially at the early stage of feedlot. Helping the feedlot producers to reduce the production cost is very important because more than 90% of meat consumed in Thailand comes from the small holders (Yimmongkol, 1990; Yimmongkol *et al.*, 2002) especially when the price of feed ingredients rise up.

Project V. Effects of cassava leaf meal in concentrate on feeding performance, carcass quality, carcass composition, some beef eating qualities and economic return of feedlot cattle

Results and discussion

Chemical composition of feedlot feed

Chemical composition of the treatment diets were analyzed and found that CP of 13.77 and 14.50%, CF of 10.60 and 8.47%, Ash of 7.63 and 9.19%, EE of 1.84 and 3.80%, NDF of 31.63 and 20.08%, ADF of 21.42 and 12.48%, Lignin of 4.78 and 3.14%, Cal/g. of 4,157.97 and 4,116.70 cal./g. for the CTRL and CLM, respectively (Table 30).

Table 30 Chemical compositions of the experimental concentrate (III.)

Chemical composition (% of DM)	CTRL	CLM
Crude protein (calculated)	14.10	14.25
Crude protein (Prox. analysis)	13.77	14.50
TDN (calculated)	77.90	79.43
Crude fiber	10.60	8.47
Ash	7.63	9.19
EE	1.84	3.80
NDF	31.63	20.08
ADF	21.42	12.48
Lignin	4.78	3.14
Cal/g.	4,157.97	4,116.70
Bulk density (g./ lit)	566.20	560.19
Price (baht / kg.)	5.10	4.84

Feedlot Performances

No significant difference was observed on ADG (1.0 and 0.78 kg./day) of the CTRL, and CLM, respectively. However, final weight (426.20 and 388.40 kg.), weight gain (150, and 117.2 kg.), FCR (6.90 and 8.80) were significantly different ($P < 0.05$) of the CTRL, and CLM, respectively. Total DM intake (1,027 and 997.55 kg.), DM intake % of body weight (2.93 and 3.02%), DM intake/day (6.83 and 6.65 kg.) and DM intake/day/kg. body wt.^{0.75} (84.56 and 85.84 g.) were not significantly different of the CTRL and CLM, respectively. Feed intake of CLM was a little bit lower than CTRL and resulted in lower final weight and weight gain. Wanapat and Rowlinson (2005) reported that condensed tannins (CT) and hydrocyanic acid were generally found in high value in matured cassava leaves but were lower in cassava hay harvested at younger stage. Barry and Manley (1984) and Reed (1995) reported that if condensed tannins in the feed exceeded 6% of dry matter, it would reduce feed

intake and digestibility. Feed cost (5.1 and 4.84 baht/kg.), feed cost / day (36.00 and 33.58 baht/day), feed cost /kg. of gain (36.21 and 44.38 baht/kg.) and palatable score (3.10 and 2.75) were not significantly different for the CTRL and CLM, respectively (Table 31).

Table 31 Effects of cassava leave meal as protein source in concentrate on feeding performance and feed cost of feedlot cattle

Feedlot Performance	CTRL	CLM	SEM	P
No. of animal	5	5	-	-
Initial wt. (kg.)	276.20	271.20	7.60	0.76
Feeding period (day)	150	150	-	-
Final wt. (kg.)	426.20 ^a	388.40 ^b	10.70	0.042
Gain (kg.)	150.00 ^a	117.20 ^b	9.32	0.034
ADG (kg./day)	1.00	0.78	0.062	0.074
FCR	6.90 ^b	8.80 ^a	0.481	0.04
DM intake (kg.)	1,027.83	997.55	33.51	0.68
DM intake (% of body wt.)	2.93	3.02	0.083	0.63
DM intake/day (kg./day)	6.85	6.65	0.22	0.68
DM intake/day/kg. body wt. ^{0.75} (g.)	84.56	85.84	2.331	0.80
Feed cost (baht/kg.)	5.10	4.84	-	-
Feed cost / day (baht/day)	36.00	33.58	1.31	0.39
Feed cost /kg. of gain (baht/kg.)	36.21	44.38	2.25	0.06
Palatability ^{1/}	3.10	2.75	0.20	0.41

Digestibility coefficient

Feces samples of the feedlot cattle were collected to analyze and determine the digestibility coefficient at 2 and 4 months of the experiment. Within treatment diets, digestion coefficient of DM (72.58 and 68.87%) and ADF (71.20 and 67.74%) appeared to be the same with no significant difference ($P>0.05$) between the cattle fed with CTRL and CLM, respectively. CTRL had the highest of digestibility coefficient of CP and OM as compared to CLM. The digestibility coefficient of CP (72.72 and 68.72%) and OM (79.71 and 75.97%) were significantly different ($P<0.01$) between the CTRL, and CLM, respectively. This might be the effect of higher digestibility of conventional protein sources in CTRL. The digestibility coefficient of CF (64.75 and 49.51%) were significantly different ($P<0.01$) and were consistent to digestibility coefficient of NDF (63.33 and 52.62%) between the CTRL, and CLM, respectively (Table 32) and were consistent to proximate analysis of CF and NDF in the treatment diets (Table 30).

Table 32 Effects of CLM in concentrate on blood urea nitrogen (BUN), blood glucose, T₃, ammonia nitrogen, volatile fatty acids, digestibility coefficient, pH and ecology of the rumen fluid of the feedlot cattle

Item	CTRL	CLM	SEM	P
BUN (0hr.) (mg%)	12.22	10.12	0.56	0.053
Blood glucose (mg%)	84.42	82.58	2.85	0.770
T ₃ (mg%)	149.8	166.8	10.14	0.500
Rumen ammonia nitrogen (mg%)	6.19	6.31	0.064	0.380
Rumen Total VFA (mmol./l)				
Acetic acid	58.59 ^b	64.32 ^a	1.39	0.030
Propionic acid	20.75	21.35	0.73	0.710
Butyric acid	11.79 ^B	12.73 ^A	0.19	0.005
Digestibility coefficient, %				
CP	72.72 ^a	68.72 ^b	1.015	0.035
OM	79.71 ^a	75.97 ^b	2.63	0.013
DM	72.58	68.87	1.26	0.150
CF	64.75 ^A	49.51 ^B	2.71	0.0001
NDF	63.33 ^A	52.62 ^B	1.94	0.0002
ADF	71.20	67.74	1.61	0.310
pH of Rumen Fluid	6.87	6.67	0.06	0.080
Protozoa (Entodiniomorphs)(x10 ⁵ cells/ml.)	2.33	1.92	0.602	0.750
Protozoa (Holotrichia) (x10 ⁵ cells/ml.)	0.08	0.14	0.024	0.160
Bacteria (x10 ⁸ cells/ml.)	2.90	3.07	0.16	0.634
Fungal zoospores (x10 ⁶ cells/ml.)	9.12 ^a	0.11 ^b	2.99	0.031

^{A,B} Means within rows with different superscripts differ (P<0.01)

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

Blood urea nitrogen, glucose and T₃

Blood urea nitrogen (BUN) indicates the protein digestibility and utilization by rumen and small intestine or the amount of urea nitrogen, a waste product of protein metabolism, in the blood. BUN in beef cattle is normally at 11-15 mg./100ml. (Byers and Moxon, 1980). Level of T₃ and T₄ indicate the digestibility of animal feed and are considered to be good indicators of the nutritional status of an animal (Capen and Martin, 1989; Riis and Madsen, 1985). No significant difference was observed (P>0.05) between blood urea nitrogen (BUN) (12.22 and 10.12 mg. %), blood glucose (84.42 and 82.58 mg. %) and T₃ (Caloriegenic hormone) (149.8 and 166.8 mg. %) of the cattle fed with CTRL and CLM, respectively (Table 32). However, the feedlot cattle fed with CLM had the highest T₃ when compared to CTRL.

Ammonia nitrogen, volatile fatty acids and pH of the rumen fluid

Rumen ammonia nitrogen ($\text{NH}_3\text{-N}$) indicated the intake and digestibility of crude protein in ruminant feed (Hammond, 1983) and correlate to BUN (Church, 1979). Satter and Slyter (1974) reported that $\text{NH}_3\text{-N}$ which was suitable for development and activity of microbial rumen should be at 5-8 mg./100ml. with the minimum requirement of 5 mg./100ml. Volatile fatty acids (VFA) are produced in large amounts through ruminal fermentation and are of paramount importance in that they provide greater than 70% of the ruminant's energy supply (Bower, 1998). It was found that ammonia nitrogen content in the rumen fluid of the cattle fed with CLM was higher than CTRL with no significant difference ($P>0.05$). Result of the ammonia nitrogen of the rumen fluid was consistent to the blood urea nitrogen (BUN). Ammonia nitrogen of the rumen fluid was 6.19 and 6.31 mg% of the cattle fed with CTRL and CLM, respectively. Propionic acid (20.75 and 21.35 mmol/l) was not significantly difference ($P>0.05$) while acetic acid (58.59 and 64.32 mmol/l) and butyric acid (11.79 and 12.73 mmol/l) of the cattle fed with CTRL and CLM, respectively was significantly different ($P<0.05$) (Table 32 and Figure16). No significant difference ($P>0.05$) was found for the pH of rumen fluid between the experimental cattle as showed in Table 32 and Figure 17.

Populations of microbial rumen

The food consumed by the ruminant goes to the rumen where there is great microbial diversity and this diversity helps in the digestion of the food consumed (Bowen, 1998). The resulted showed no significant difference of the amount of protozoa in both groups of Entodiniomorphs (2.33 and 1.92×10^5 cells/ml.) and Holotrichia (0.08 and 0.14×10^5 cells/ml.) and bacteria (2.90 and 3.07×10^8 cells/ml.) of the cattle fed with CTRL and CLM, respectively (Figure 18 and 20). However, fungal zoospores (11.12 and 0.11×10^6 cells/ml.) of the cattle fed with CTRL and CLM, respectively, was significantly different ($P<0.05$) (Figure 19). This was the effect of condensed tannin in CLM concentrate which had direct effect on the nutrients digestibility. This result was consistent with Barry and Manley (1984) and Reed (1995) who reported that if condensed tannins in the feed exceeded 6% of dry matter, it would reduce feed intake, microbial rumen and digestibility.

Carcass quality and composition

After the feeding trial, all feedlot cattle were sent to the slaughter house to study carcass quality and composition. From Table 33, It is found that the slaughtering weight (429.6 and 393.2 kg.) of cattle were not significantly different ($P>0.05$) between the cattle fed with CTRL and CLM, respectively. Carcass weight (235.8 and 213.8 kg.) and lean weight (192.5 and 170.8 kg.) were significantly different ($P<0.05$) between the feedlot cattle fed with CTRL and CLM, respectively (Table 33), and consistent to the slaughtering weight, ADG, FCR and digestibility of

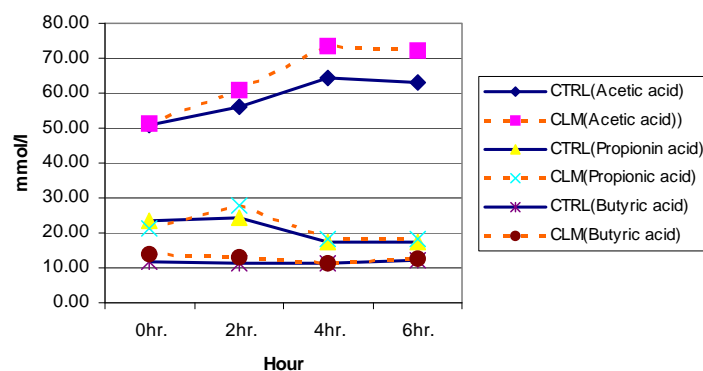


Figure 16 Effects of cassava leaf meal in concentrate on VFA of the rumen fluid

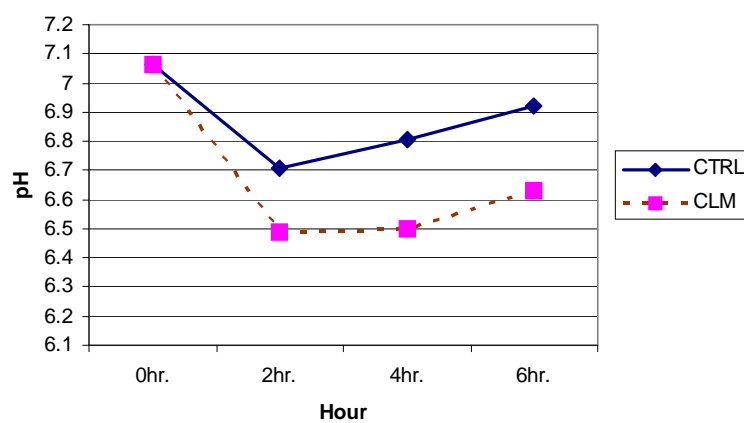


Figure 17 Effect of cassava leaf meal in concentrate on pH of the rumen fluid

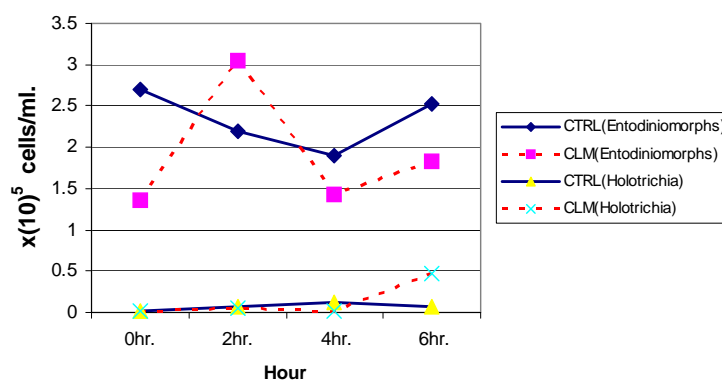


Figure 18 Effect of cassava leaf meal in concentrate on direct count of protozoa in the rumen fluid

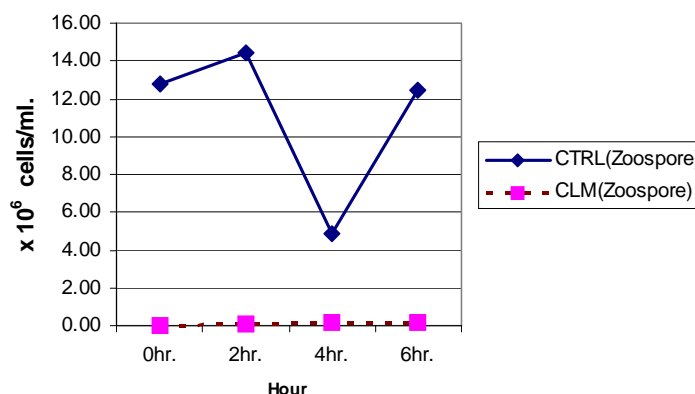


Figure 19 Effect of cassava leaf meal in concentrate on direct count of fungal zoospores in the rumen fluid

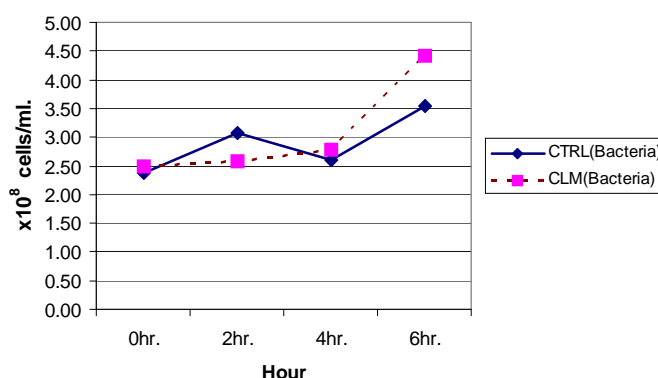


Figure 20 Effect of cassava leaf meal in concentrate on direct count of bacteria in the rumen fluid

the nutrients (Table 31 and 32). Carcass percentage (54.9 and 54.5%), loin eye area (59.96 and 57.30 cm²), loin eye area/100 kg. of carcass weight (25.43 and 26.81 cm²/100 kg.), marbling (1.4 and 1.2), fat thickness (0.28 and 0.28 cm.), meat color (2.25 and 3.4) and fat color (3.75 and 3.80) were not significantly different ($P>0.05$).

Lean percentage (44.8 and 44.3%), hide weight (44.56 and 44.81 kg.), hide percentage (10.37 and 11.3%), bone weight (50.87 and 52.74), weight of visceral fat (16.00 and 14.42 kg.) and visceral fat percentage (6.80 and 6.68%) were not significantly different ($P>0.05$). Lean weight (192.5 and 170.8 kg.) and bone percentage (11.82 and 13.42%) were significantly different ($P<0.05$) between the cattle fed with CTRL and CLM, respectively. It is found that meat color of the cattle feed with CLM tended to be better than CTRL. Loin eye area of the cattle fed with CTRL was better than CLM but loin eye area/100 kg. of carcass weight of CLM seemed to be better than CTRL. The fat thickness and marbling score of the cattle in

both groups were quite low because they were 2 years of an average age (not castrate) and consistent to the report of Jongjalernya (2003).

Table 33 Carcass quality, carcass composition and some beef eating qualities of dried cassava leaf meal as a protein source in concentrate of feedlot cattle

Item	CTRL	CLM	SEM	P
No. of animals (heads)	5	5	-	-
Slaughtering weight (kg.)	429.60	393.20	11.13	0.10
Carcass weight (kg.)	235.80 ^a	213.80 ^b	5.69	0.04
Dressing (%)	54.90	54.50	0.66	0.76
Lean weight (kg.)	192.50 ^a	170.80 ^b	5.73	0.05
Lean (%)	44.80	44.30	0.61	0.74
Hide (kg.)	44.56	44.81	1.72	0.95
Hide (%)	10.37	11.30	0.32	0.16
Bone (kg.)	50.87	52.74	1.20	0.47
Bone (%)	11.82 ^B	13.42 ^A	0.35	0.01
Abdominal fat (kg.)	16.00	14.42	0.66	0.26
Abdominal fat (%)	6.80	6.68	0.25	0.83
Marbling ^{1/}	1.40	1.20	0.15	0.55
Rib Fat (cm.)	0.28	0.28	0.01	0.95
Meat Color ^{2/}	2.25	3.40	0.42	0.19
Fat Color ^{3/}	3.75	3.80	0.28	0.94
Loin eye area (cm.) ²				
- Total (cm.) ²	59.96	57.30	2.10	0.56
- Per 100 kg. of carcass weight (cm) ² /100 kg.	25.43	26.81	2.61	0.44
Shear force (kg.)	2.28	2.26	0.32	0.99
Tenderness ^{4/}	2.98	3.42	0.26	0.43
Juiciness ^{5/}	3.23	3.40	0.19	0.67
Meat flavor ^{6/}	3.13	3.38	0.14	0.40
Overall satisfaction ^{7/}	2.98	3.42	0.18	0.24

^{A,B} Means within rows with different superscripts differ (P<0.01)

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

^{1/} Marbling score from 1 to 5; 1= no marbling and 5 = highest marbling score

^{2/} Meat color score from 1-7; 1= pale pink, 2= soft pink, 3= pink, 4= light red, 5= red, 6= medium dark red and 7= dark red

^{3/} Fat color score from 1-7; 1= turbid white, 2= medium turbid white, 3= light turbid white, 4= white, 5=light pinky white, 6= medium pinky white, 7= pinky white

^{4/} Tenderness score from 1-5; 1= excellence, 2= good, 3= medium, 4= fair, 5= poor

^{5/} Juiciness score from 1-5; 1= excellence, 2= good, 3= medium, 4= fair, 5= poor

^{6/} Meat flavor score from 1-5; 1= excellence, 2= good, 3= medium, 4= fair, 5= poor

^{7/} Overall satisfaction score from 1-5; 1= excellence, 2= good, 3= medium, 4= fair, 5= poor

Shear force and sensory evaluation

The overall satisfaction of the consumers on beef are general appearance, colour, price and some beef eating qualities such as tenderness, juiciness, marbling, smell and taste (Kantapanit, 1986). Results from the Warner Bratzler Shear device indicated that shear force (2.28 and 2.26 kg.) was not significantly difference ($P>0.05$) between the cattle fed with CTRL and CLM. The results from sensory evaluation indicated that tenderness (2.98 and 3.42), juiciness (3.23 and 3.4), meat flavor (3.13 and 3.38) and overall satisfaction (2.98 and 3.42) were not significantly different ($P>0.05$). However, tenderness, juiciness, meat flavor and overall satisfaction of the cattle feed with CTRL tended to be better than the other fed with CLM (Table 33). The result from this experiment revealed that the use of CLM as a protein source in concentrate did not influence beef eating qualities of the feedlot cattle.

Table 34 Effects of cassava leave meal as protein source in concentrate on economic return of feedlot cattle

Carcass quality and profit	CTRL	CLM	SEM	P
Initial wt. (kg.)	276.20	271.20	7.60	0.76
Live wt. (kg.)	429.6	393.2	11.133	0.103
Carcass wt. (kg.)	235.8 ^a	213.8 ^b	5.691	0.044
Lean wt. (kg.)	192.5 ^a	170.8 ^b	5.731	0.05
Total feed cost (baht)	5,399.6	5,037.5	195.804	0.39
Cost of feedlot cattle (baht)	11,876.6	11,661.6	-	-
Cost of feedlot cattle / kg. body wt. (baht/kg.)	43	43	-	-
Other production cost (baht)	1,030	1,030	-	-
Total production cost (baht)	18,306.19	17,729.09	195.804	0.39
Carcass price (baht) ^{1/}	20,994.4	19,146.8	541.310	0.086
Sale price/kg. body wt. (baht)	48.85	48.80	0.585	0.97
Profit / head (baht)	2,688.17	1,417.69	350.242	0.064
% Profit	14.89	8.05	1.96	0.08

^{1/} Carcass wt. > 190 kg. = 90 baht/kg. ; Carcass wt. < 190 kg. = 88 baht/kg.

Economic return of the feedlot cattle

The total feed cost and total production cost of the cattle fed with CTRL was higher than CLM. The total feed costs were 5399.60 and 5,037.50 baht and total

production costs were 18,306.19 and 17,729.09 baht of the cattle fed with CTRL and CLM, respectively. The production cost of the experimental feedlot cattle was studied to determine the economic return. The feedlot cattle fed with CTRL had the highest carcass price than CLM (20,994.40 and 19,146.80 baht) due to the carcass weight. Moreover, the feedlot cattle fed with CTRL had more profit when compared to CLM (2,688.17 and 1,417.69 baht) as same as percentage of the profit (14.89 and 8.05%), respectively (Table 34).

The result of this experiment indicated that cassava leaf meal has enough potential to be used as a protein source in concentrate for feedlot cattle. Even though, the feedlot performance and nutrient digestibility was lower than that concentrate used conventional protein sources, due to the effect of condensed tannin, but still satisfied the economic return. Carcass qualities, carcass composition and some beef eating qualities didn't show any difference. However, meat color and loin eye area/100 kg. of carcass weight tended to be better ($P = 0.19$ and 0.44) which is very important to fit the needs of local markets and consumers. Cassava leaf meal has enough potential to be use as a protein source in feeding ration especially for the small farmers who raise feedlot cattle surrounding the cassava planting area. Helping the feedlot producers to reduce the production cost is very important because of more than 90% of meat consumption in Thailand comes from the small holders (Yimmongkol, 1990; Yimmongkol *et al.*, 2002) especially when the price of feed ingredients rise up.

Project VI. Farmers' adoption and comments on using of cassava pulp and leaf meal as cattle feed

Results and discussion

Socio – economic status of the farmers

Fifty four farmers from every part of Thailand who formulated and produced the cattle feed used in their farms were involved in collecting the data of using cassava pulp and leaves as cattle feed. Forty nine farmers (91%) were male and 5 were female (9%) and they were from the central part of Thailand, north, south, northeast and east of 60, 11, 6, 19 and 4%, respectively. The average age of the farmers of 20-30, 31 - 40, 41 - 50 and over 50 yrs. were 19, 50, 24 and 7%, respectively. Many farmers were well educated with bachelor and master degrees of 46 and 17% while the others had certificated of primary or high school or a diploma of 13, 11 and 13%, respectively. Twenty one farmers (39%) raised cattle as their major occupation while 33 farmers (61%) raised cattle as their minor occupation with the main income coming from an occupation of government officer, private trade, agriculture, private company, private sector or other livestock production of 6, 18, 36, 9, 21 and 9%, respectively.

The technical knowledge of the farmers on beef cattle farming and feed management derived (>1 sources) from the training program (including technical advices), experience, field trip, education (in agriculture) and others at 74, 52, 37, 20 and 6%, respectively. The farmers themselves believed that they have the technical knowledge at the level of high, fair and poor at 6, 79 and 15%, respectively. Many farmers were a member of beef cattle breeders association or cooperative (>1 option) while less were not a member. It was found that 28% were not member of any groups (general farmers), 33% were a member of BCAT (Beef Cattle Breeders Association of Thailand), 39% of KBBA (Kamphaeng Saen Beef Breeders Association of Thailand), 18% of Brahman Breeders Association of Thailand, 24% of KU Kamphaeng Saen Campus Beef Producer Cooperative Ltd. (KU – KPS Co-op. Ltd.), 24% were the members of Improving of Genetics and Performance of Kamphaeng Saen Beef Cattle Research Project (organized by Buffalo and Beef Production Research and Development Center), 4% of other beef producer cooperative and 2% were the leader of beef cattle production group. (Figure 21, 22 and Table 35)

Farm characterization of the objective farmers

The types of cattle farming of the farmers were dairy cattle, beef cattle (breeding stock), beef cattle + feedlot cattle and feedlot cattle of 6, 39, 46 and 9%, respectively. The small holders had an average of 10 heads of cattle while the largest farm had over 1,500 cattle. The cattle breeds (>1 breeds) were Brahman and Brahman crossbred, Kamphaeng Saen, Charolais crossbred, native cattle, Hindu Brazil and crossbred and others of 83, 39, 7, 11, 5 and 9%, respectively. The feedlot production

system was analysed and found that 22% of the farmers produced high quality beef (KU Beef), 19% were both of high quality beef and local quality beef, 24% were local quality beef and 35% were breeding stocks. Most of the high quality beef productions (prime quality) were K.U. Beef from Kamphaeng Saen steers and organized by the KU - KPS Co-op. Ltd. and 41% of the objective farmers were involved in high quality beef production. The smallest feedlot production had only 5-10 steers while the biggest had more than 200 heads of steers.

The local quality beef production used young bulls of Brahman crossbred with feeding periods of 3 - 4 months and shared about 43% of the objective farmers. The smallest local feedlot production had only 5-10 young bulls while the biggest had more than 1,500 heads of young bulls. It was found that 63% of farms formulated and produced dietary on farm, 26% of farms produced feed for use and sale and 11% quit producing feed because of the high price of feed ingredient did not fit the economics for fewer cattle. The types of feed formulated and produced on farms were concentrate, both of total mixed ration and concentrate and TMR of 59, 35 and 6%, respectively. Source of roughage used in farms (>1 source) were natural grass, pasture, straw, treated straw, silage, pineapple waste and others of 44, 65, 50, 15, 52, 13, 20 and 6%, respectively. Type of pastures (>1 source) were Legume, Para grass, Pangola grass, Ruzi grass, Guinea grass, Napier grass, sugar cane silage and others (crossbred sorghum grass) of 11, 7, 26, 26, 28, 15, 4 and 17%, respectively.

Farmer's adoption of using cassava pulp and cassava leaves as cattle feed.

It was found that 42 farmers (78%) used cassava pulp and cassava leaves as cattle feed for both feed supplements and as feed ingredients. Cassava pulp and leaves were used in the form of wet cassava pulp (WCP), dried cassava pulp (DCP), dried cassava leaves or cassava leaf meal (CLM) and ensiled cassava leaf (ECL). In the case of using cassava pulp and leaves, it was found that percentage of the farmers who used WCP, DCP, DCP+CLM and CLM were 14, 29, 19 and 38%, respectively. The reasons of adoption were to reduce feed cost, local feed ingredient or feed stuff, confidence in using and on farm planting as cattle feed (root and leaves) of 42, 28, 20 and 10 %, respectively. The reason for rejection of using were no confidence (22%), distance from planting area and starch factories (10%), condition of starch factory (7%), used of other feed ingredient (7%), required by other private companies (3%) and increase of prices (3%). The demand of DCP and CLM per month by the farmers who formulated and produced feedlot feed are shown in Figure 29 and 30 The levels of DCP used in dietary feedlot were 5 - 40% of feed composition with the maximum level of 60% while CLM from 3 - 20% with the maximum level of 30% (Table 37).

Fourteen farmers (33%) had some problems with using DCP and CLM in dietary feedlot while 28 farmers (67%) had on problem. The problems were price increases (24%), unstable quality (26%) and a lack of supply (50%) of DCP and CLM. Satisfaction and displeasure of using DCP was showed in Table 37. It was found that the acceptable price of DCP ranged from 2.5 - 3.5 baht/kg. or at 50 - 60% of the price of cassava chips while the price of cassava chips should not exceed more

than 6.0 baht/kg. The acceptable price of WCP ranged from 0.5 - 0.8 baht/kg. while the price of CLM ranged from 4.0 - 6.0 baht/kg. The idea of tapioca planting as cattle feed was increasingly accepted by the farmers and found that 5 (21%) of 24 farmers who used CLM as a protein source in feedlot diet accepted this idea.

It was found from this research that farmers had changed their concept on cassava pulp and leaves from the agricultural waste product to animal feed. Many farmers complained that remixing dried cassava pulp into cassava chips or pellet was unfair to them in terms of quality and supply of feed ingredient. They hoped that the government or to whom it concerned would emphasize on this problem and try to find solution by reporting the actual amount of cassava pulp produced and pushing the processing of DCP as feed ingredient with acceptable price. Many farmers had enough confidence to use DCP as a feed ingredient instead of cassava chips to reduce the production cost, especially the feedlot production when the price of cassava chips was higher. The acceptable price of DCP was 2.5 - 3.5 baht/kg. or at 50 - 60% of the price of cassava chips while the price of cassava chips should not exceed more than 6.0 baht/kg. On farm planting of cassava was increasingly accepted by the farmers with the purpose of harvesting the leaves as a protein source (CLM) in feedlot diets and production of cassava roots for cassava chips themselves to reduce the production cost, especially the backyard feedlot producers. On the other hand, the farmers around the cassava planting areas and cassava starch factories will have new source of income from drying cassava pulp, leaves or ensiled cassava leaves and selling them directly or indirectly to the feedlot producers.

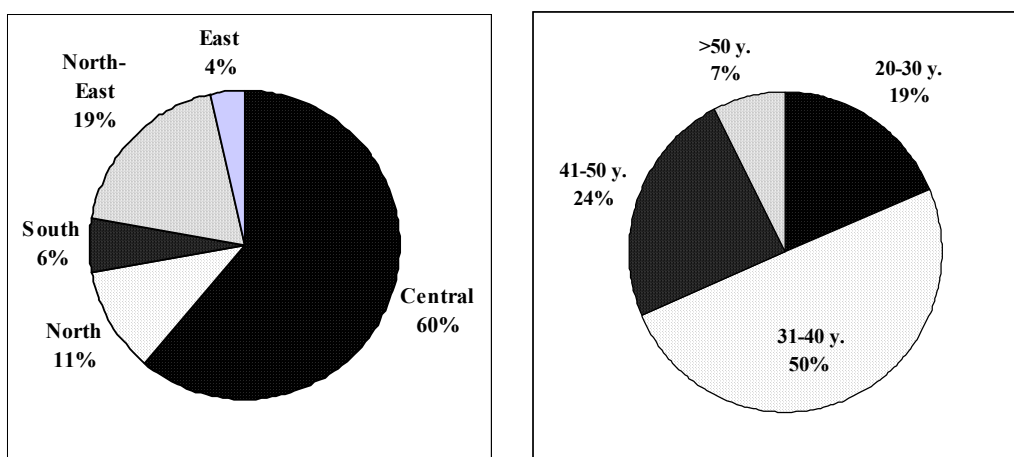


Figure 21 Farm location and age of the objective farmers

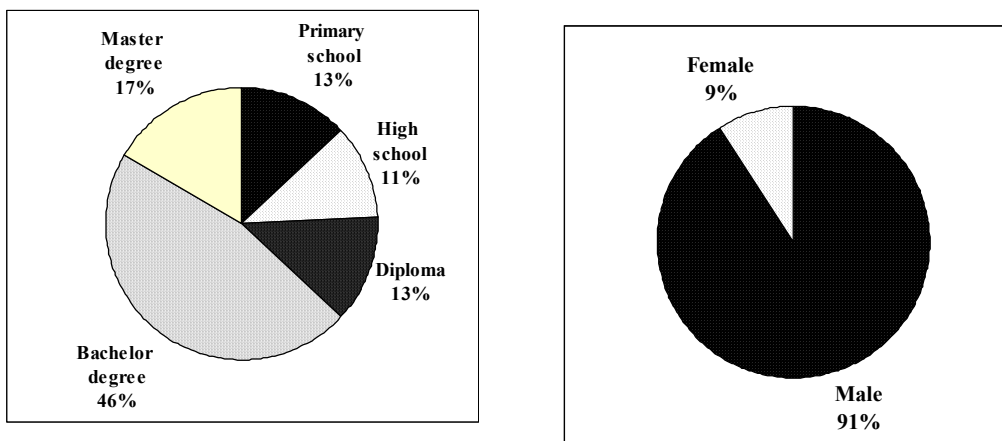


Figure 22 Education of the objective farmers

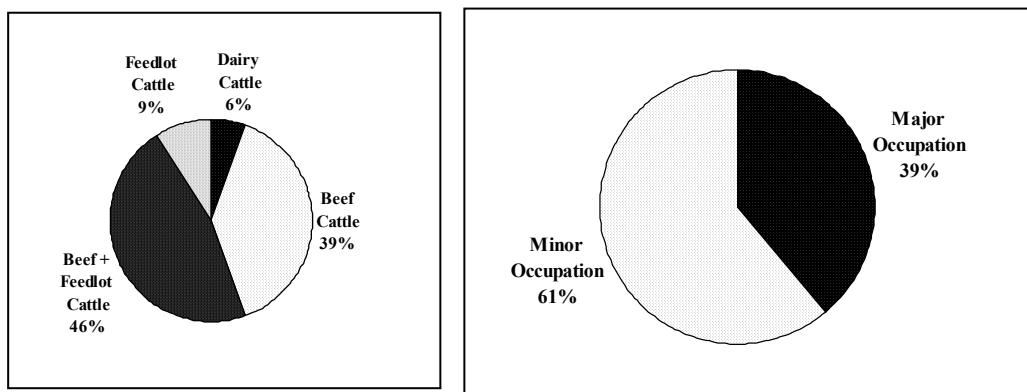


Figure 23 Type of cattle farming and occupation on cattle farming of the objective farmers

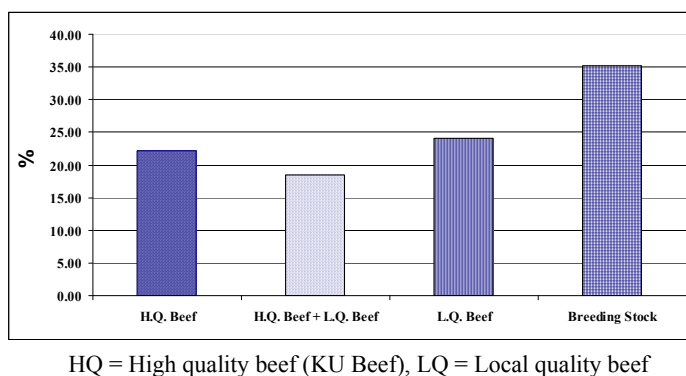


Figure 24 Type of feedlot cattle and breeding stock of the objective farmers

Table 35 Socio-economic status of the objective farmers

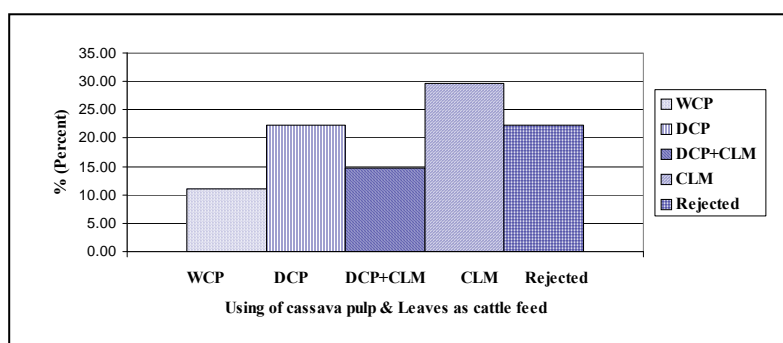
Item	Total (n=54)	%
Farmers	54	100
Male	49	90.74
Female	5	9.26
Age (years)		
- 20-30	10	18.52
- 31-40	27	50.00
- 41- 50	13	24.07
- > 50	4	7.41
Education		
- Primary school	6	11.11
- High school	7	12.96
- Diploma	7	12.96
- Bachelor degree	25	46.30
- > Master degree	9	16.67
Location		
Central	33	61.11
North	6	11.11
South	3	5.56
North- east	10	18.52
East	2	3.70
Type of Cattle Farming		
Major Occupation	21	38.89
Minor Occupation	33	61.11
No. of cattle (heads)		
<10	1	1.85
10 – 50	24	44.44
51 – 100	7	12.96
101- 200	13	24.07
200 – 500	6	11.11
501 – 1000	1	1.85
> 1000	2	3.70
Breed of beef cattle (>1 breed)		
Kamphaeng Saen beef cattle	21	38.89
Brahman and Brahman crossbred	45	83.34
Native cattle	6	11.11
Hindu brazil	3	5.56
Others	9	16.67
Source of technical knowledge (>1 source)		
Education in agriculture	11	20.37
Experience	28	51.85
Training course	40	74.07
Field trip	20	15.75
Others (internet, technical book and etc.)	3	2.36

Table 36 Farm characterization of the objective farmers

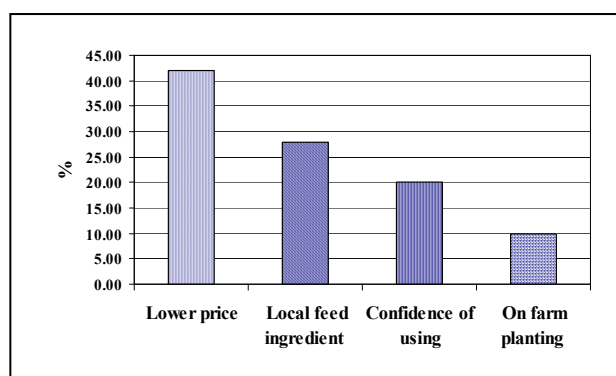
Item	Total (n=54)	%
Farmers	54	100
Type of cattle farming		
Dairy cattle	3	5.56
Beef cattle	21	38.89
Beef cattle + feedlot cattle	25	46.30
Feedlot cattle	5	9.26
Breed of beef cattle (>1 breed)		
Kamphaeng Saen beef cattle	21	38.89
Brahman and Brahman crossbred	45	83.34
Native cattle	6	11.11
Hindu brazil	3	5.56
Others	9	16.67
Type of feedlot cattle		
High quality beef (KU. Beef)	12	22.22
High quality beef (KU. Beef) + local quality beef	10	18.52
Local quality beef	13	24.07
Breeding stock + dairy cattle	19	35.19
High quality beef (KU. Beef) (heads)		
<10	4	18.18
10 – 50	9	40.91
51 – 100	5	22.73
101- 200	3	13.64
> 200	1	4.55
Local quality beef (heads)		
20 – 50	4	30.77
51 – 100	6	46.15
101- 200	0	0
200 – 500	1	7.69
500 – 1000	1	7.69
> 1000	1	7.69
Purpose of dietary feed formulated in farms		
Farm use	34	62.96
Farm use and sell	14	25.93
Quit (price of feed ingredient, few cattle and etc.)	6	11.11
Type of feed		
Concentrate	28	58.33
TMR.	3	6.25
Concentrate + TMR.	17	35.42
Source of roughage (>1 source)		
Natural grass	24	44.40
Pasture	35	64.80
Straw	27	50.00
Treated straw	8	14.80
Corn Stover	28	51.90

Table 36 (continued)

Item	Total (n=54)	%
Silage	7	13.0
Pineapple meal	11	20.4
Others	3	5.6
Type of pasture (>1 source)		
legume	6	11.11
Para grass	4	7.41
Pangola grass	14	25.93
Ruzi grass	14	25.93
Guinea grass	15	27.78
Napier grass	8	14.81
Sugar cane silage	2	3.70
Others (X-sorghum grass)	9	16.67



WCP = Wet cassava pulp, DCP = Dried cassava pulp, CLM = Cassava leaf meal (dried cassava leaves)

Figure 25 The Use of cassava pulp and cassava leaves as cattle feed of the objective farmers**Figure 26** Adopted reasons of using cassava pulp and leaves as cattle feed.

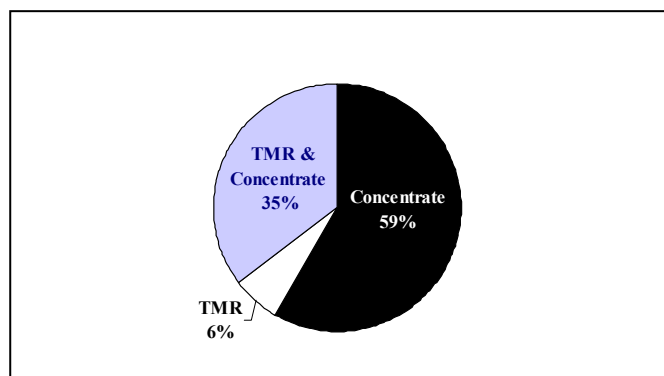
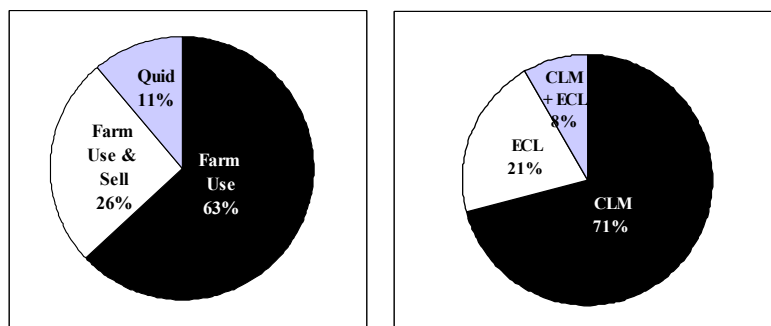


Figure 27 Type of dietary feed formulated in farms of the objective farmers



ECL = Ensiled cassava leaves, CLM = Cassava leaf meal (dried cassava leaves)

Figure 28 The purpose of dietary feed formulated in farms and type of cassava leaves used as cattle feed

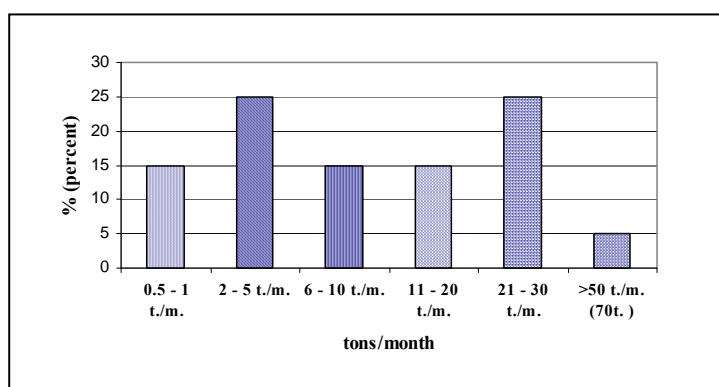


Figure 29 The requirement of dried cassava pulp/month of the objective farmers

Table 37 Farmers' adoption of using cassava pulp and cassava leaves as cattle feed

Item	Total (n=54)	% (% of using)
No. of farmers	54	100
Using of cassava pulp and leaves as cattle feed	42	77.78 (100)
- WCP ^{1/}	6	11.11 (14.29)
- DCP ^{2/}	12	22.22 (28.57)
- DCP + CLM ^{3/}	8	14.81 (19.05)
- CLM	16	29.63 (38.10)
Not using	12	22.22
Type of using cassava pulp and leaves as cattle feed		
Cassava leaves	24	44.44 (100)
- CLM	17	31.48 (70.83)
- CLM + Silage	2	3.7 (8.33)
- Silage	5	9.26 (20.83)
Cassava pulp	26	48.15 (100)
- WCP	6	11.11 (23.08)
- DCP	20	37.04 (76.92)
Adopted of using cassava pulp and leaves (>1 reason)	50	100
Reduce feed cost	21	42
In the area of planting or starch factory	14	28
Confidence of using	10	20
Cassava plantation as cattle feed	5	10
Rejected of using cassava pulp and leaves (>1 reason)	31	100
No confidence	3	9.68
Far from planting area	10	32.26
Low quality	3	9.68
Problem on storing	6	19.35
Condition of starch factory	3	9.68
Use other feed ingredients	2	6.45
Require by other private companies	2	6.45
Price increasing	1	3.23
Others	1	3.23
Dried cassava pulp in dietary feedlot (normal)	20	37.04 (100)
5 - 10%	4	20
11 - 15%	5	25
16 - 20 %	3	15
21 - 25 %	5	25
25 - 30 %	2	10
40 %	1	5
Dried cassava pulp in dietary feedlot (maximum)	20	37.04 (100)
< 20%	11	55
30 - 40 %	6	30
50 %	2	10
> 60 %	1	5

Table 37 (continued)

Item	Total (n=54)	% (% of using)
Amount of dried cassava pulp in dietary feedlot/m.	20	37.04 (100)
≤ 5 tons/m.	8	40
6 – 10 tons/m.	3	15
11 – 20 tons/m.	3	15
≥ 20 tons/m.	6	30
Cassava leaf meal in dietary feedlot (normal)	12	22.22 (100)
< 5 %	2	16.67
6 – 10 %	5	41.67
11 – 15 %	4	33.33
16 – 20 %	1	8.33
Cassava leaf meal in dietary feedlot (maximum)	12	22.22 (100)
10 %	6	50.00
15 %	2	16.67
20 %	2	16.67
25 %	2	16.67
Amount of cassava leaf meal in dietary feedlot/m.	12	22.22 (100)
≤ 3 tons/m.	8	66.67
4 – 10 tons/m.	2	16.67
≥ 10 tons/m.	2	16.67
Reasons of using cassava pulp and leaves in dietary feedlot (>1 reason)	64	100
price	37	57.81
Confidence of using	18	28.13
Pretest of using	7	10.94
others	2	3.13
Source of cassava leaf meal	24	100
Private sector	6	25.00
Leaf harvesting	13	54.17
Cassava plantation as cattle feed	5	20.83
Other protein source in case of using DCP ^{2/} in dietary feedlot	45	100
Leucaena leaf meal	4	8.89
Cassava leaf meal	8	17.78
Palm oil meal	11	24.44
Mung bean meal	4	8.89
Soybean meal	12	26.67
Coconut meal	1	2.22
Peanut meal	1	2.22
Sunflower meal	1	2.22
Dried brewery grain	1	2.22
others	2	4.44

^{1/} WCP = Wet cassava pulp, ^{2/} DCP = Dried cassava pulp, ^{3/} CLM = Cassava leaf meal

Table 37 (continued)

Item	Total	% (% of using)
	(n=54)	
Problems of using DCP ^{2/} and CLM ^{3/} in dietary feedlot	42	100
No problem	14	33.33
Problems (>1 reason)	28 (42)	66.67 (100)
- increasing of price	10	35.71 (23.81)
- unstable of the quality	11	39.29 (26.19)
- support of DCP and CLM	21	75.00 (50.00)
Satisfaction of using DCP in dietary feedlot	42	100
Satisfied (>1 reason)	34	80.95 (100)
- reduced production cost	23	54.76 (50.00)
- better feedlot performance and health	10	23.81 (21.74)
- convenience in feedlot management	7	16.67 (15.22)
- better of carcass and meat quality	5	11.91 (10.87)
- others (reduce bad smell of manure and etc.)	1	2.38 (2.17)
Displeasure	8	19.05 (100)
- increasing of price	5	11.91 (62.50)
- unstable of the quality	1	2.38 (12.50)
- low palatability and dusty of dietary feedlot	2	4.76 (25)
Optimum price of DCP	23	100
≤ 2.5 baht/kg.	14	60.88
3.0 baht/kg.	3	13.04
3.5 baht/kg.	6	26.09
≥ 4.0 baht/kg.	0	0
Price of DCP not excess than % of cassava chips price	20	100
≤ 40 %	9	45
50 %	7	35
60%	4	20
> 60%	0	0
Optimum price of CLM	24	100
≤ 4 baht/kg.	18	75
5 baht/kg.	3	12.50
6 baht/kg.	3	12.50
> 6 baht/kg.	0	0

^{1/} WCP = Wet cassava pulp, ^{2/} DCP = Dried cassava pulp, ^{3/} CLM = Cassava leaf meal

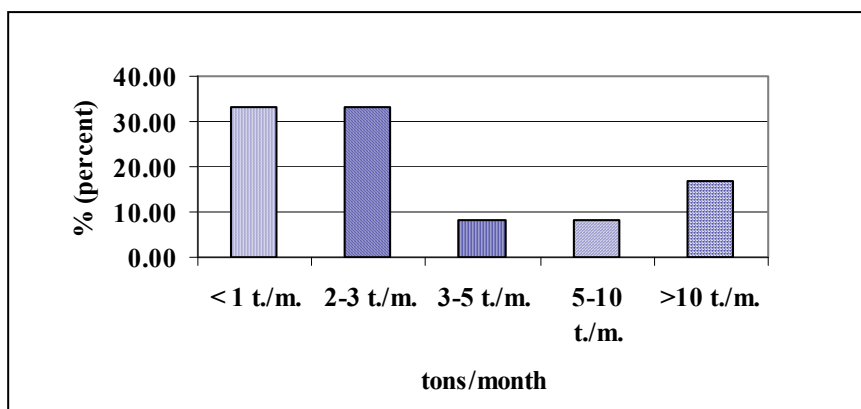


Figure 30 The requirement of cassava leaf meal/month of the objective farmers

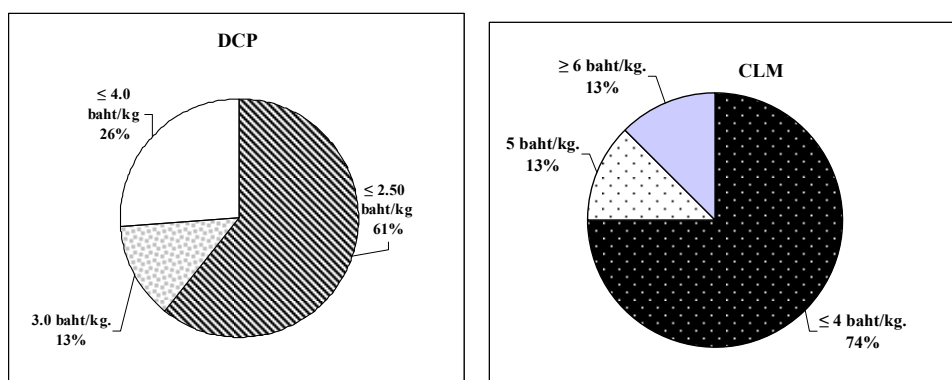


Figure 31 Acceptable price of dried cassava pulp (DCP) and cassava leaf meal (CLM)

Farmer information and recommendations

Wet cassava pulp (WCP)

1. Many farmers fed WCP to the animals without ensiling (to decrease the toxic of hydrocyanic content) because they do not have enough knowledge and know-how.

2. Some starch or sweetener factories want to sell WCP back to the one who sell fresh root with the purpose of illegally remixing back to the cassava chips.

3. Queued up for at least for 1-2 days before receiving and transporting due to the high demand of WCP.

4. WCP had some technical problems in storing due to the strong smell which affected the other people in the surrounding area.

5. WCP could not be used as the main feedlot feed due to the high moisture content which affected the DM intake.

6. WCP sometimes had some problems in supplying due to the season of harvesting fresh roots and higher demand by livestock farming, private feed companies and feed millers.

7. Establishment of high quality pasture was the gate way to solving the problem in the future.

8. The quality of WCP fluctuated even though it came from the same source of supply and was still sold at the same price.

Dried cassava pulp (DCP)

1. The acceptable price of DCP was 2.5 - 4.0 baht/kg. or at 50 - 60% of the price of cassava chips or 2.0 baht cheaper while the price of cassava chips should not exceed more than 6.0 baht/kg.

2. Remixing dried cassava pulp into cassava chips or pellet was unfair to the farmers in terms of quality and supply of feed ingredient

3. The government, cassava starch producers or whom it concerned should emphasize on this problem and try to solve it by reporting the actual amount of cassava pulp and pushing the processing of DCP as feed ingredient with acceptable price.

4. The result from 3 can solve the problem of supplying DCP to the farmers and the unnecessary bulk storing which affects the over all production cost.

5. It is necessary to have the special unit to standardize the quality of both cassava chips and DCP.

6. Due to the economic and energy crisis, higher price of all feed ingredients caused many swine and poultry producers change their idea of using DCP as a feed ingredient.

7. From the beginning of 2008, price of DCP in some provinces was up to 4.50 - 5.00 baht/kg.

8. DCP is highly required by private feed companies and feed millers. Some private feed companies contacted directly to the group of feedlot producers (Sakonnakhon and Mukdahan Province) to supply the feedlot feed and buy nearly all of DCP produced in the north east of Thailand.

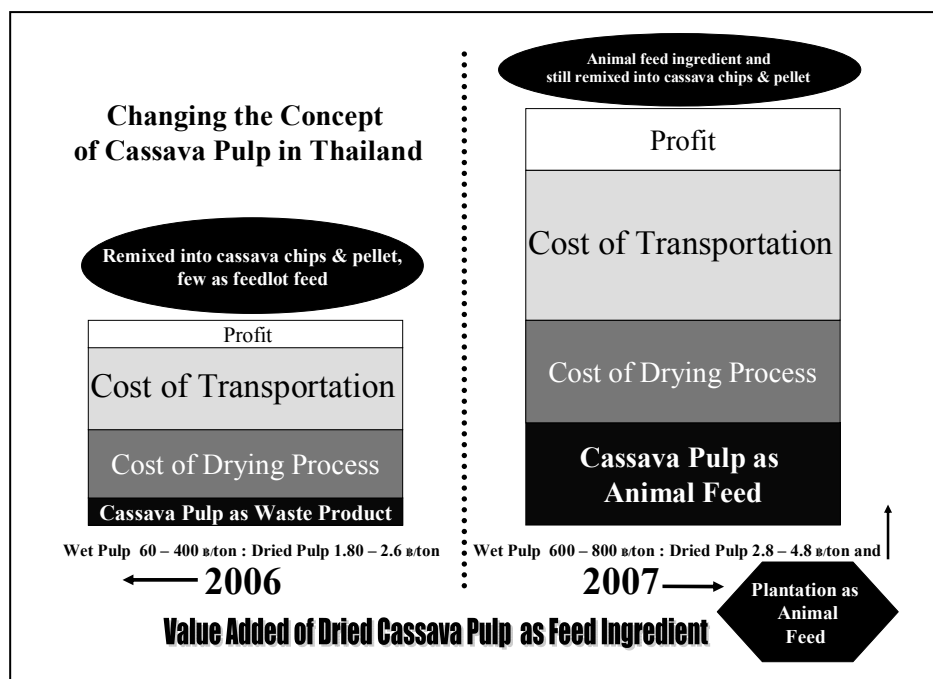


Figure 32 Concept of the utilization of cassava pulp in Thailand

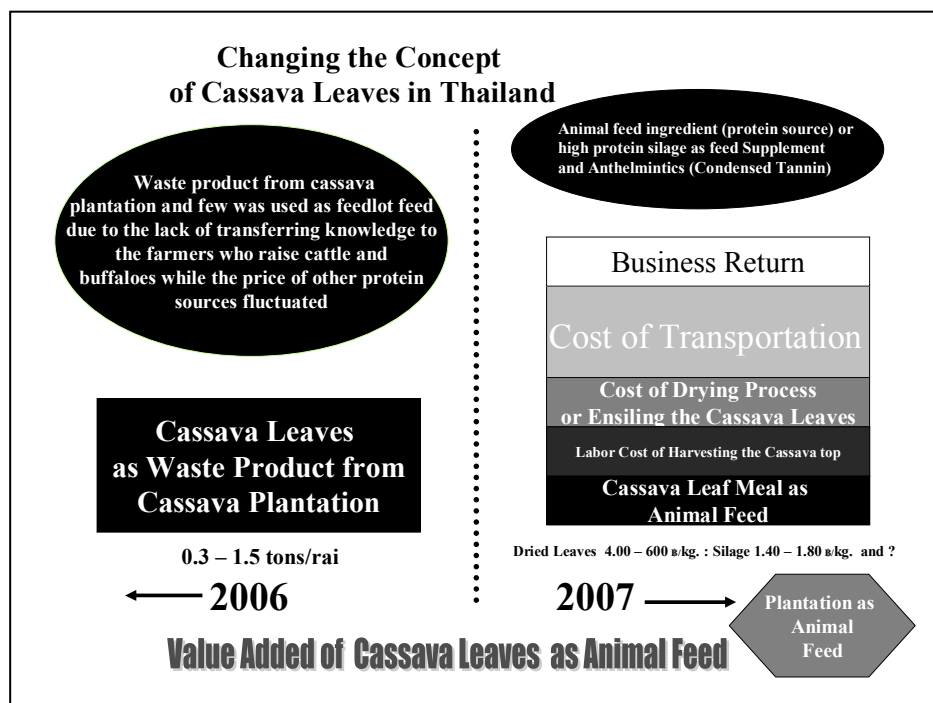


Figure 33 Concept of the utilization of cassava leaves in Thailand

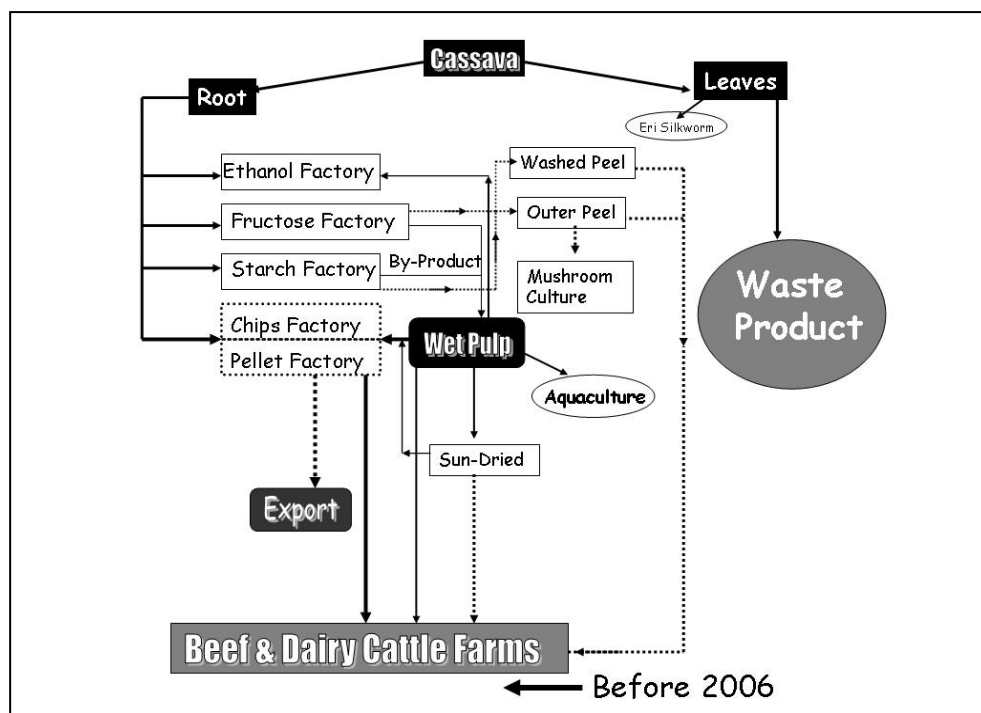


Figure 34 The utilization of cassava pulp and leaves in Thailand before 2006

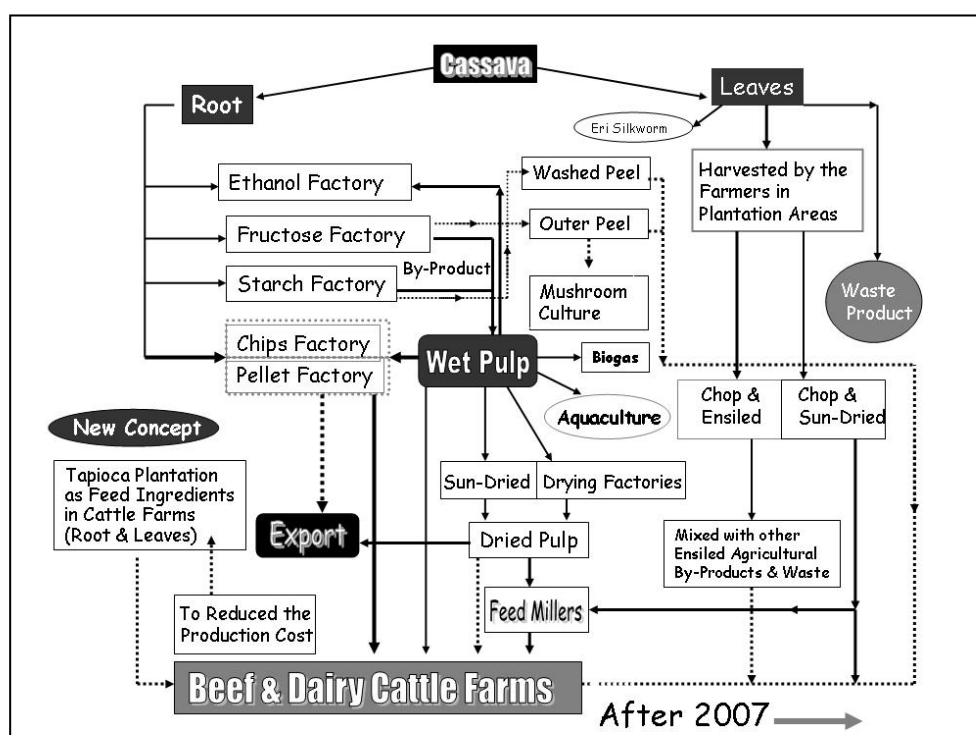


Figure 35 The utilization of cassava pulp and leaves in Thailand after 2007

9. The quality of DCP from drying factories is better than sun dried DCP but more dusty. Molasses is necessary to reduce the dustiness of feedlot diet.

10. Some farmers recommended that using DCP in feedlot diet could reduce the strong smell of feedlot.

11. Carcass and beef quality (local beef quality) are better and acceptable by many butchers and fit the need of consumers due to the low fat content.

Cassava leaf meal (CLM)

1. Many rural farmers who raise cattle had the experience of losing their cattle and buffaloes by eating fresh cassava leaves and were still hesitate to feed them even though they had been trained of how to reduce the HCN content.

2. Transferring the appropriate technology and knowledge to the farmers especially the rural farmers is very important to help them have enough confidence in using cassava leaves as animal feed.

3. Ensiled cassava leaf is one of the high quality roughage helping to get better body condition due to the higher protein content. Condensed tannins contained in CLM or ensiled cassava leaf demonstrated a potential role as a tannin-protein complex that increases rumen by-pass protein and reduces gastro-intestinal nematodes.

4. Mixing ensiled cassava leaf with other silage to increase protein content demonstrated a potential role in preventing lose by mold.

5. On farm planting of cassava was increasingly accepted by the farmers with the purpose of harvesting the leaves as a protein source (CLM) in feedlot diets and produced cassava chips themselves to reduce the production cost, especially the backyard feedlot producers.

6. By pushing the formation of groups of the rural producers, the farmers around the cassava planting area and cassava starch factories will have new source of income from drying cassava pulp, leaves or ensiled cassava leaves and selling them directly or indirectly to the feedlot producers.

Generals

1. Transferring the knowledge to the farmers by on farm and short term training course is very important to help the poor farmers.

2. Technical leaflets or documents on the use of cassava pulp and leaves as cattle feed are needed by the local farmers and should have the appropriated technology and easily to understand.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Wet cassava pulp (WCP) and ensiled cassava pulp (ECP)

1. It is better to use ECP as a feed supplement (Skunmun *et al.*, 2005).
2. ECP can be used as the main feed for breeding cows and supplement with high quality roughage, protein source and mineral-vitamin lick.
3. Mixing the small amount of wet cassava pulp to the silage will improve the quality and period of ensiling. Jintanavanich and Juttupornpong (2008) reported that wet cassava pulp has up to $10^6 - 10^7$ colonies/g. of lactic acid bacteria while the other feed ingredients have only $10^2 - 10^3$ colonies/g. Mixing of cassava pulp with other roughage, especially cassava leaves can reduce the time of fermentation from 21 days to 10-14 days and HCN content in ensiled cassava leaves decline which has no effect to the animal.
4. Mixing with concentrate as complete feed is more suitable for feedlot cattle and should not be fed exceedingly to the cattle. The refusals of the complete feed will easily turn putrid due to the high moisture content. Three to five daily feeding times will increase feed intake and avoid the refusal of the complete feed.
5. Prolonging of ensiling wet cassava pulp by 1-2 weeks before feeding to the animal can reduce the moisture content and improve the feed intake.
6. Feedlot producers near by the cassava starch or sweetener factories have more potential to reduce the production cost by using cassava pulp for feedlot cattle and following the 1-5 methods.

Dried Cassava pulp (DCP)

1. Dried (sun drying) cassava pulp has more potential to be used as feed ingredient or storing for feedlot diet.
2. Rural farmers around the cassava starch or sweetener factories can earn more money by producing sun dried cassava pulp and selling it directly or indirectly to the feedlot producers in other areas.
3. The feedlot performances of the feedlot cattle fed with concentrate which used dried cassava pulp instead of cassava chips at the level of 10 – 30 % didn't show any difference.

4. Dried cassava pulp still has enough potential to be used as a feed ingredient in feeding rations especially for the small farmers who raise feedlot cattle around the cassava planting area, cassava starch and cassava sweetener factories.

5. The feedlot performances of the feedlot cattle fed with concentrate which used dried cassava pulp instead of cassava chips (100 % instead) didn't show any difference.

6. Helping the feedlot producers to reduce the production cost is very important, especially when the price of feed ingredients rise up. It is estimated that 90% of meat consumed (the local quality beef) comes from the small holders.

7. Carcass qualities, carcass composition and some beef eating qualities of the feedlot cattle fed with concentrate which used dried cassava pulp instead of cassava chips didn't show any difference.

8. The acceptable price of DCP was 2.5 - 4.0 baht/kg. or at 50 - 60% of the price of cassava chips or 2.0 baht cheaper while the price of cassava chips should not exceed more than 6.0 baht/kg.

9. Adulterating of DCP into cassava chips or pellet was unfair to the farmers in terms of quality and supply of feed ingredient.

10. The government, cassava starch producers or whom it concerned should emphasize on this problem and try to solve it by reporting the actual amount of cassava pulp and pushing the processing of DCP as feed ingredient with an acceptable price.

11. The result from 10 can solve the problem of supplying DCP of the farmers and the unnecessary bulk storing which affected the over all production cost.

12. Due to the economic and energy crisis, higher price of all feed ingredients caused many swine and poultry producers to change the idea of using DCP as feed ingredient. From the beginning of 2008, the price of DCP in some provinces of Thailand is 4.50 – 5.00 baht/kg.

13. DCP is highly required by private feed companies and feed millers. Some private feed companies contacted directly to the group of feedlot producers (Sakonkakhon and Mukdahan Province) to supply the feedlot feed and buy nearly all of DCP produced in north east of Thailand.

14. The quality of DCP from drying factory is better than sun dried DCP but more dusty. Molasses is necessary to reduce the dustiness of feedlot diet.

15. Some farmers recommended that using DCP in feedlot diets could reduce the strong smell of the feedlots.

16. Carcass and beef quality (local beef quality) are better and acceptable by many butchers and fit the need of customers due to the low fat content.

Cassava leaf meal (CLM)

1. The feedlot performances and nutrient digestibility of the feedlot cattle fed with concentrate which using CLM replacing of the conventional protein sources were lower however still satisfied the economic return.

2. Carcass qualities, carcass composition and some beef eating qualities of the feedlot cattle fed with concentrate which used CLM instead of the conventional protein sources (leucaena leaves, soyhulls and cocohulls) didn't show any difference. However, meat color and loin eye area/100 kg. of carcass weight tended to be better which is very important to fit the needs of local markets and consumers.

3. The acceptable price of CLM was 4 - 6 baht/kg. Many rural farmers who raise cattle had the experience of losing their cattle and buffaloes by eating fresh cassava leaves still were not daring to feed them even though they've been trained on how to reduce the HCN content.

4. Transferring the appropriate technology and knowledge to the farmers especially the rural farmers is very important to help them have enough confidence to use cassava leaves as animal feed.

5. Ensiled cassava leaf is one of the higher quality roughages to help get better body condition due to the higher protein content. The condensed tannins contained in both of CLM and ensiled cassava leaf demonstrated a potential role as a tannin-protein complex to increase rumen by-pass protein and to reduce gastrointestinal nematodes.

6. Mixing ensiled cassava leaf with other silage to increase protein content demonstrated potential roles in preventing lose by mold.

7. On farm planting of cassava was increasingly accepted by the farmers with the purpose of harvesting leaves as a protein source (CLM) in feedlot diet and produced cassava chips themselves to reduce the production cost, especially the backyard feedlot producers.

8. By pushing the formation of groups of the rural producers, the farmers around the cassava planting area and cassava starch factories will have new supplemented income from drying cassava pulp, leaves or ensiled cassava leaves and selling it directly or indirectly to the feedlot producers.

Recommendations

1. The government, cassava starch producers or whom it concerned should emphasize on the problem of remixing DCP into cassava chips or pellet and try to solve it by reporting the actual amount of cassava pulp and pushing the processing of DCP as feed ingredient with an acceptable price.
2. It is necessary to have the special unit or institute to standardize the quality and price of both cassava chips and DCP.
3. Many butchers, feedlot producers and the government officers of DLD (Department of Livestock Development) interested in these results especially the carcass quality which had low fat content. Promoting the use of DCP to reduce production cost and improve carcass quality is one of the launch projects to reduce the illegal use of salbutamol (meat stimulant) which is toxic to consumers. Suphan Buri was the first province who launches this project.
4. Transferring the knowledge to the farmers by the on farm and short term training course is very important to help the poor farmers.
5. Technical leaflets or documents on the use of cassava pulp and leaves as cattle feed are needed by the local farmers and should contained the appropriated technology and be easy to understand.

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