CLEAN CASSAVA CHIPS FOR ANIMAL FEEDING IN THAILAND

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ABSTRACT

Thailand has been the top cassava products exporter to the world market for decades. However, there was a decline in exports of cassava pellets to the EU market and this has affected the prices of both cassava fresh roots and dry products in the country. Therefore, greater domestic use of cassava for animal feeding in Thailand is being encouraged.

Cassava has been promoted for use in animal feeds in Thailand for more than a decade, but adoption has been very limited due to the unsuitable quality of cassava products (cassava chips and pellets) available, and the relatively high price of the products (after mixing with a protein source) when compared to conventional cereals, such as maize and broken rice. In 1997, when Thailand suffered an economic crisis as well as a severe slump in cassava prices due to the sharp decline of cassava pellets exports to the EU market, the Animal Nutrition Research and Development Center (ANRDC) of Kasetsart University and the Thai Tapioca Development Institute (TTDI) decided to promote more actively the use of cassava for domestic animal feed production in Thailand.

The activities included the transfer of technology to the farmers in the proper use of cassava for animal feeding via seminars, workshops, publications T.V media, etc. They also included technologies to improve the quality of cassava chips to be employed by the farmers. Prime quality (clean) cassava chips are now produced by some cassava processors and this has facilitated the successful use of cassava in animal diets. At present, the Department of Interior Trade (DIT) and the Department of Foreign Trade (DFT), Ministry of Commerce, together with ANRDC and TTDI, have promoted more production and more uses of prime quality cassava chips, both for animal feeding in the country and for export to the world market.

Proper feeding of prime quality cassava chips to animals, including pigs, poultry (chickens and ducks) and cattle, both in laboratory and in commercial animal farms, have shown a very satisfactory and a comparable performance as compared to those animals fed with maize diets. But cassava diets also have an advantage in terms of better digestibility, health improvement of the animals, which has led to a much reduced use of antibiotics in animal production, and a considerable reduction in the odor of manure. Cassava has been extensively used in pigs and cattle (beef and dairy) diets at substitution levels of 40-60%. A series of studies on the advantages of using cassava in animal diets have been conducted at ANRDC of Kasetsart University and the results are very promising.

INTRODUCTION

Cassava is an important economic root crop grown in Southeast Asia as well as in tropical Africa and Central America. The crop plays a very important role in the economy of Thailand since a great number of farmers, especially those in the northeastern part of the country, rely on cassava for much of their income.

The fresh roots, which contain approximately 60% moisture, are mainly utilized for the production of cassava starch or dried cassava chips and pellets for animal feeds.

1. Cassava Cultivation in Thailand

Cassava is one of the most important economic crops in Thailand. The country produces approximately 18-22 million tonnes of fresh roots annually, of which

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approximately 8 million tonnes are utilized for cassava starch production and the remaining 10-14 million tonnes are processed into 4.5-6.0 million tonnes of dried cassava chips and pellets for animal feed. The chips are mainly utilized domestically while the pellets are exported mainly to the European Union (EU) countries. But in 1993, the EU initiated a CAP reform policy, with the objective to reduce the price of cereals grown in the EU countries; this has resulted in a decrease in the price of cassava and has gradually reduced the amount of cassava pellets exported to the EU market. However, more cassava chips are utilized domestically for animal feed; therefore, the production volume is still maintained and the cassava price crisis has been relieved.

Cassava production is scattered throughout the country but the major production areas are in the northeastern and eastern parts of Thailand, while considerable volumes of cassava are also produced in the northern and western parts of the country. Planting of cassava generally starts in April and May, at the beginning of the rainy season, and harvesting is normally done in October to March of the following year during the dry season. It is the good weather in Thailand during the cassava harvesting season that ensures that Thai cassava products are of high quality, compared to the products of some other countries.

In addition, in Thailand cassava varieties have been developed that produce high yields and have high starch contents; these are now widely distributed to the growers. For example, Kasetsart 50 (KU 50), which was developed by the Department of Agronomy, Faculty of Agriculture, Kasetsart University; and Rayong 5, Rayong 60 and Rayong 90 which were developed by the Department of Agriculture, Ministry of Agriculture and Co-operatives, are new cassava varieties which produce high yields and have high starch contents; these are now commonly grown by farmers in the country.

2. Toxic Substances in Cassava and their Detoxification

Fresh cassava roots contains the cyanogenic-glycoside, linamarin, which is hydrolyzed into glucose and hydrocyanic acid (HCN) by the activity of linamarase enzyme when the root is damaged or cut into small pieces. The released HCN slowly evaporates into the atmosphere, so the level of HCN in the cassava products is reduced.

Dried cassava chips are produced by chopping the fresh roots into small pieces and then sun-drying for 3-4 days; this, greatly reduces the HCN content of the chips to levels that are non-toxic to animals. Khajarern *et al*. (1982) have demonstrated that sun-drying of cassava chips for 6 days reduced the HCN content of the chips from 111.83 to 22.97 ppm (**Table 1**). Storing of dried cassava chips also further reduces the HCN content of the cassava product. Storing of dried cassava chips for five days reduced the HCN content of the product from 87.14 to 36.25 ppm (**Table 2**). Steam assisted pelleting of cassava further reduced the HCN content to 11.82 ppm (Khajarern *et al*., 1979).

It can be concluded that production of dried cassava chips involving 3-6 days of sun-drying and a few days of storage before shipment to the feed manufacturer or users lowers the HCN content in the product to non-toxic levels. Additional storage of the cassava product at the feed mill will further reduce the HCN content and provide an additional safety margin for the users. The use of cassava pellets eliminates any risk of HCN toxicity to the animals.

From our field experiences, the authors have promoted the use of cassava chips in pig and poultry feeds for the past decade. Good quality cassava chips produced in

Thailand, in which the moisture content is less than 14%, have on average an HCN content below 30 ppm, and have produced no HCN toxicity in animals.

HCN in cassava may be eliminated by cooking, steaming, drying, ensiling as well as by washing. Some of these processes are not practical for preparation of cassava products for animal feeds, but they may be employed in the preparation of cassava for human consumption.

Table 1. Effects of length of sun drying on the HCN content of cassava chips.

Days of sun drying	HCN content (ppm)
0	111.83
1	111.96
2	110.96
3	109.96
4	90.72
5	52.22
6	22.97

***Source**: Khajarern et al., 1982.*

Table 2. Effects of length of storage on HCN content of cassava chips.

Days of sun drying	HCN content (ppm)
0	87.14
1	56.76
2	40.11
3	29.52
4	31.46
5	36.25

***Source :** Khajarern et al., 1982.*

3. Production of Dried Cassava Chips and Pellets

Dried cassava chips and pellets are common cassava products used in animal feeds. A schematic diagram of their production process is shown in **Figure 1**. Freshly harvested roots are cleaned by washing or sifting, then chipped into small pieces and sun-dried on concrete floors for 3-6 days, depending on weather conditions and sunlight. The chips are regularly turned over by mechanical raking throughout the drying period. Dried chips normally contain 13-14% moisture and are kept in the warehouse for a few days before shipment to the users.

Cassava chips may be ground, steamed and pelletized into cassava pellets which are more compact, less dusty and very convenient for transportation and bulk shipment. However, some additives such as palm kernel cake or palm oil should be added in order to facilitate the pelletizing process. Some additives which have a high crude fiber content may affect the nutritional value of cassava pellets; therefore, more attention should be paid to quality control when using cassava pellets in animal diets.

Dried cassava chips are bulky and dusty, and are not appropriate for bulk shipment and transportation by ship. However, chips are easy to determine their quality and are very appropriate for domestic use in the feed industry.

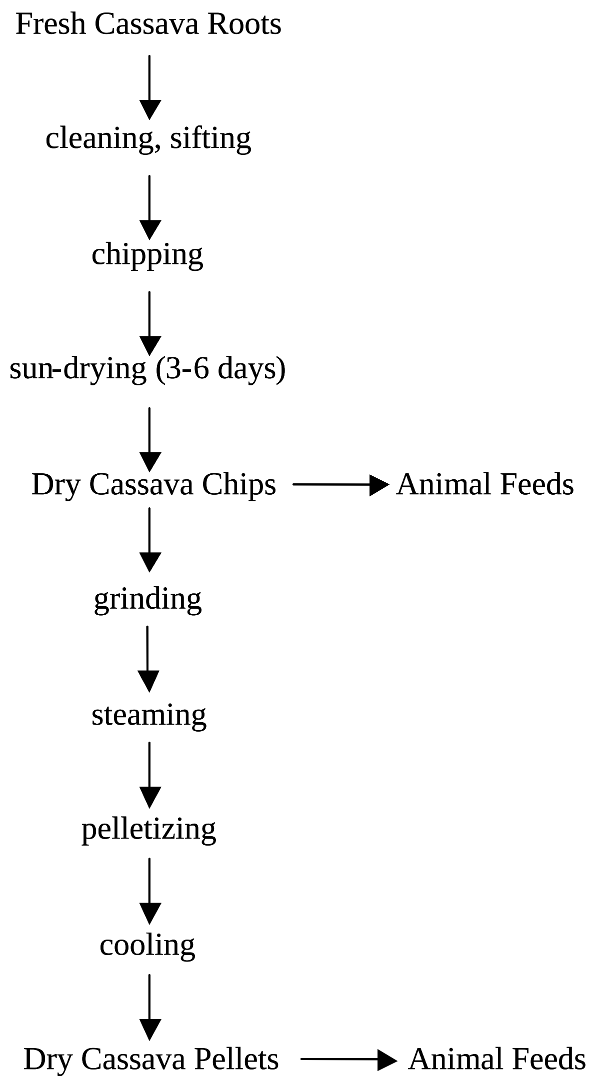

Figure 1. Schematic diagram of the cassava chips and pellets production process.

4. Nutritive Value of Dried Cassava Chips and Pellets

The chemical composition of cassava compared to maize, sorghum and broken rice is shown in **Table 3**. In general, cassava is an excellent energy feed ingredient but contains very little protein (approximately 2%) and has low levels of amino acids as compared to other feed ingredients. Cassava products are also low in fat and contain no pigments for poultry. The chemical composition of cassava chips and pellets produced in Thailand is shown in **Table 4**. In general, the crude fiber and ash contents of cassava pellets may be higher than cassava chips due to the addition of pelleting additives such as palm kernel cake or some vegetable oil for lubricants. The nutritive value of pelleted cassava varies according to the types and amount of pelleting additives included. Additives that increase the crude fiber and ash levels in the pelleted cassava will lower the nutritive value of the product.

Table 3. Comparison of chemical composition of cassava, broken rice, maize and sorghum.

	Cassava	Broken rice	Maize	Sorghum
Crude protein (%)	2.00	8.00	8.00	11.80
Lysine (%)	0.09	0.27	0.25	0.23
Methionine (%)	0.03	0.27	0.19	0.16
Methionine+Cystine (%)	0.06	0.32	0.39	0.27
Tryptophan (%)	0.02	0.10	0.09	0.10
Threonine (%)	0.07	0.36	0.32	0.33
Isoleucine (%)	0.07	0.45	0.34	0.44
Arginine (%)	0.12	0.36	0.40	0.39
Leucine (%)	0.12	0.71	1.17	1.38
Phen + Tyr (%)	0.12	1.15	0.81	0.96
Histidine (%)	0.03	0.18	0.25	0.22
Valine (%)	0.09	0.53	0.46	0.55
Glycine (%)	0.08	0.71	0.33	0.33
Metab. energy for pigs (Mcal/kg)	3.26	3.60	3.30	3.14
Metab. energy for poultry (Mcal/kg)	3.50	3.50	3.37	3.25
Fat (%)	0.75	0.90	4.00	3.00
Crude fiber (%)	4.00	1.00	2.50	3.00
Calcium (%)	0.12	0.03	0.01	0.04
Avialable phosphorus (%)	0.05	0.04	0.10	0.10

Table 4. Standard of cassava chips and pellets produced in Thailand.

	Cassava chips	Cassava pellets
Moisture (%)	13	13
Crude protein (%)	2	2
Crude fiber (%)	3.5-4.0	4.0-4.5
Ash /Sand	2	2
Nitrogen-free extract (%)	75-80	73-78

The crude fiber and ash contents of cassava chips depend very much on the quality of fresh roots and the processing techniques. Good quality fresh roots, which are clean and have minimal or no adulteration of stems or woody parts will produce good quality cassava chips with low crude fiber and ash contents. Washing or sifting of fresh roots to eliminate sand and soil before chipping significantly lowers the ash content. Production of large cassava chips not only minimizes the dustiness during processing but also prolongs the drying period and thus reduces the HCN content. Peeling of fresh roots before processing will also lower the crude fiber and ash contents of the chips. However, peeling is not recommended as it is very tedious and impractical as well as uneconomical for preparation of cassava for animal feed. The use of good quality cassava chips or pellets produced from unpeeled roots normally result in very satisfactory performances of the animals when compared to broken rice or maize.

The nutritive value of cassava products also depends on the contents of organic and inorganic parts of the cassava. Khajarern *et al*. (1979) have categorized the nutritive value of cassava products as chemical grade or quality score according to the following equation:

Chemical grade or quality score = OM – [ADF + (CF – 3)]

where OM = % organic matter
ADF = % acid detergent fiber
CF = % crude fiber

Cassava products may be classified into four grades: A,B,C and D when the quality score is >80, 75–80, 70-75 and <70, respectively. However they did not report any information on tested results of the effects of the quality score on the performance of the animals.

Phansurin *et al*. (2002) and Lokaewmanee *et al*. (2002) have shown that the metabolizable energy (ME) content of cassava chips are inversely related to the levels of crude fiber in the feed ingredients **(Table 5)**. Increasing the levels of crude fiber significantly ($P<0.05$) decreased the ME content of the cassava chips, both in pig and in chicken diets. It is advisable to use only high-quality cassava products in animal feeds; these not only have low fiber contents and thus allow a higher inclusion rate of the product in the animal diets, but they also have a higher nutritive value, which is worth the higher price.

Table 5. Metabolizable energy (ME) of cassava starch and chips with different levels of crude fiber in pig and chicken diets.

Types of cassava products	Crude fiber (%)	Pigs 20 kg	Pigs 60 kg	Broilers 3 weeks	Broilers 7 weeks
		ME (Kcal/kg)			
Cassava starch	0	3,741	3,756	3,819	3,848
Chips of peeled roots	2.3	3,540	3,574	3,712	3,749
Prime quality chips	3.9	3,356	3,385	3,587	3,615
Regular quality chips	5.2	3,189	3,291	3,283	3,335

Source: *Punsurin et al., 2002; Lokaewmanee et al., 2002.*

Cassava starch is highly digestible due to the soft-starch as it consists of more than 80% amylopectin. Cassava has the highest digestibilities in dry matter, organic matter and energy in different parts of the digestive tract of growing pigs when compared to maize, sorghum and barley (**Table 6**) (Reas, 1996). The cassava diet showed a significant linear decline in dry matter, organic matter and energy from the stomach down to the caecum, resulting in an almost complete digestion before the large intestine. The maize diet had lower digestibilities for dry matter, organic matter and energy compared to cassava, but these differences were not statistically significant. Sorghum and barley were not significantly different from each other but were significantly lower than cassava and maize in the digestibilities of dry matter, organic matter and energy after the small intestine. It can be concluded that cassava is an excellent energy source and can replace the cereal grains in growing pig diets.

Table 6. Nutrient digestibility (%) of cassava, maize, sorghum and barley in the different parts of the digestive tract and anus (faeces) of growing pigs.

Diets	Stomach	Small intestine	Caecum	Large intestine	Faeces
Dry Matter					
cassava	30.6	59.0	87.5 [a]	89.1 [a]	90.3
maize	1.4	59.3	82.5 [a]	87.5 [ab]	88.2
sorghum	4.0	54.8	74.2 [b]	84.3 [bc]	87.6
barley	16.5	63.5	69.1 [b]	81.4 [c]	83.0
LSD	NS	NS	8.12	3.29	
Organic Matter					
cassava	30.2 [a]	61.6	88.8 [a]	90.9 [a]	92.7
maize	1.0 [b]	57.0	83.7 [a]	89.4 [ab]	90.1
sorghum	-7.8 [b]	56.3	76.2 [b]	86.8 [b]	89.6
barley	12.2 [ab]	64.3	72.7 [b]	83.4 [c]	84.0
LSD	19.8	NS	7.4	40.5	
Energy					
cassava	28.3 [a]	54.4	86.8 [a]	89.0 [a]	90.6
maize	2.0 [b]	50.4	81.9 [a]	87.6 [a]	88.3
sorghum	-7.6 [b]	49.6	72.5 [b]	83.5 [b]	86.8
barley	2.2 [b]	59.4	68.6 [b]	80.3 [c]	82.3
LSD	12.0	NS	8.9	2.8	

Source: *Reas, 1996.*

Cassava products may be contaminated with mold growth under standard production practices, but it appears that the molds produce very little or no aflatoxins or other mycotoxins. Scudamore *et al*. (1997) studied the occurrence of mycotoxins in 330 samples of raw ingredients used for animal feeding in the 186 feed mills in the United Kingdom in 1992. They reported that no cassava samples were found to be contaminated with aflatoxins or other mycotoxins, while samples of maize, rice bran, palm kernel meal, cottonseed meal, wheat and barley were found to be contaminated with aflatoxin B1, fumonisin B1 and B2, ochratoxin A or zearalenone. Protein enriched cassava (PEC), which is produced by two days of fermentation of cassava with *Aspergillus niger* followed by two days of fermentation with *Saccharomyces cereviseae* can totally replace maize in growing finishing pig diets (Laosriratanachai, 1986). Fermentation with these fungi produced heavy mold growth on the substrate but there were only trace amount of aflatoxins in the PEC product. Results of our own survey also indicate that pieces of heavily molded cassava chips collected from cassava chipping yards in Thailand contain only trace amounts of zearalenone and no aflatoxins (Sukanya Juttupornpong, personal communication). These findings are in agreement with the practical results of using cassava in animal diets in

Thailand; there were no reported incidences of aflatoxins or other mycotoxin toxicities in cassava diets fed to pigs, cattle and poultry including ducks. Cassava may be classified as a clean or free-of-toxin feed ingredient for animals feeding.

5. Cost Comparison of Cassava Products to Maize and Other Cereals

Although cassava and maize are classified as energy feed ingredients, cassava contains less protein and fat than maize. In addition, cassava contains no pigment for yolk and skin coloring in poultry. It is necessary, therefore, to equalize the nutritive value of cassava products before any cost comparison can be made.

Cassava-maize equivalent mixture (CMEM) is a combination of cassava, soybean meal (SBM) and synthetic amino acids to increase the protein and amino acid content in cassava to be equivalent to those of maize.

CMEM-1 is a mixture of 0.87 kg of cassava + 0.13 kg of soybean meal (SBM) + 0.001 kg of Dl-methionine, which supplies crude protein, amino acids and metabolizable energy (ME) equivalent to maize.

CMEM-2 is a mixture of 0.845 kg of cassava + 0.13 kg of SBM + 0.025 kg of rice bran oil + 0.001 kg of Dl-methionine, which also supplies crude protein, amino acids, ME and fat equivalent to maize.

CMEM-3 is a mixture of 0.85 kg of cassava + 0.15 kg of extruded full-fat soybean + 0.001 kg of Dl-methionine which also supplies crude protein, amino acids, ME and fat equivalent to maize.

The chemical compositions and prices of CMEM-1, CMEM-2, CMEM-3 and maize are shown in **Table 7**.

CMEM-1 is appropriate for cost comparison of cassava to maize in swine diets where fat content is not considered as an important factor.

CMEM-2 and 3 are appropriate for cost comparison of cassava to maize in poultry diets where fat and linoleic acid contents are very important to the productivity of the animals.

The feasibility of including cassava in animal feeds, therefore, depends not only on the price of cassava itself, but also on the prices of soybean meal, extruded full-fat soybeans, rice bran oil and the Dl-methionine as well. All the CMEM formulations contain no pigment and the additional cost of natural or synthetic pigments need to be added when including cassava in poultry diets.

6. Advantages of Cassava in Animal Feed Rations

Studies on the utilization of cassava for animal feeds have been conducted for more than two decades. Oke (1978) have reported that cassava products are good energy feed ingredients for both mono-gastric and ruminant animals. The starch in cassava is highly digestible when compared to that of maize due to the high content of amylopectin. Cassava can be used as a sole source energy feed ingredient in pig, poultry and ruminant diets, but attention should be paid to HCN and protein as well as amino acid contents in cassava products. There have been a number of studies of the use of cassava in animal rations in Thailand and the results of the studies indicate a great potential for cassava to replace the conventional energy feed ingredients such as maize, broken rice and sorghum, which have commonly been used in animal diets in the region.

Table 7. Ingredients, price and nutritional composition of three cassava-maize equivalent mixtures (CMEM) as compared to those of maize.

	CMEM-1	CMEM-2	CMEM-3	Maize
Ingredients (%)				
Maize	-	-	-	1.00
Cassava	0.87	0.845	0.85	-
Soybean meal	0.13	0.13	-	-
Extruded full-fat soybeans	-	-	0.15	-
Rice bran oil	-	0.25	-	-
Dl-methionine	0.001	0.001	0.001	-
Price (baht/kg)	3.34	3.60	3.77	4.70
Nutritional composition				
Crude protein (%)	7.5	7.5	7.5	8.0
ME-swine (Mcal/kg)	3.25	3.39	3.30	3.30
ME-poultry (Mcal/kg)	3.35	3.48	3.47	3.37
Fat (%)	0.72	3.20	3.39	3.50
Fiber (%)	4.12	4.03	3.90	2.50
Lysine (%)	0.43	0.43	0.44	0.25
Methionine + Cystine (%)	0.31	0.31	0.31	0.39
Tryptophan (%)	0.09	0.09	0.10	0.09
Threonine (%)	0.28	0.28	0.32	0.32
Calcium (%)	0.14	0.13	0.14	0.01
Available phosphorus (%)	0.07	0.20	0.22	0.30

6.1 Pigs

Khajarern and Khajarern (1986) have reported that growing-finishing pigs (17-100 kg) fed a cassava diet had lower average daily gain and a higher feed conversion ratio than those fed with broken rice and sorghum diets, but the differences were not statistically significant (**Table 8**). Pigs on cassava diets tend to have lower feed intake due to the bulkiness of the diet, which may lead to a lower animal performance.

Chalorklang *et al*. (2000a) studied the effects of cassava meal substituted for broken rice in diets for weaned pigs (4-8 weeks). Weaned pigs on a 100% cassava diet (Diet 4) had a similar average daily weight gain and feed conversion ratio as those on the broken rice diet (Diet 1) (**Table 9**). Cassava starch has been shown to be very easily digestible by weaned pigs and produces minimum scouring and minimum unfavorable effects to the health of the animal.

Wu (1991) fed weaned pigs, aged 28 days (7.1 kg), a daily basal protein concentrated diet (41.0% protein) at 3% body weight together with ground cassava at 2% body weight and found that the diet resulted in an average gain of 451 g/day and a feed conversion ratio of 1.23.

Chalorklang *et al*. (2000b) also studied the effects of cassava substituted for maize in diets for growing-finishing pigs (30-100 kg). Pigs fed a 100% cassava diet (Diet 4) had slightly higher average daily gains but also slightly higher feed conversion ratios as compared to those on a diet of 100% maize (Diet 1). However, the differences were not statistically significant (**Table 10**). Pigs on cassava diets required less number of days to attain market weight while carcass characteristics of pigs on every experimental diet were not significantly different.

Table 8. Effect of the utilizatin of broken rice, sorghum and cassava diets for growing-finishing pig on their performance.

	Broken rice	Sorghum	Cassava
Initial weight (kg)	17.04	16.68	16.89
Final weight (kg)	104.08	103.43	102.09
Average daily gain (kg)	0.62	0.61	0.52
Average daily feed intake (kg)	1.84	1.93	1.72
Feed conversion ratio	3.00	3.19	3.30
Dressing percentage	72.31	73.22	72.31
Loin-eye area (inch^2)	4.55	4.55	4.62

Source: *Khajarern and Khajarern. 1986.*

Table 9. Effect of the substitution of broken rice by cassava meal in diets for weaned pigs (4-8weeks) on their performance.

	Diet 1	**Diet 2**	**Diet 3**	**Diet 4**
Levels of substitution:	0	50%	75%	100%
Levels of cassava in diets:	0	24%	34%	43%
No. of animals	8	8	8	8
Initial weight (kg)	7.35	7.46	6.75	7.70
Final weight (kg)	18.53	20.24	17.64	18.39
Total weight gain (kg)	11.23	12.40	10.78	10.69
Average daily weight gain (kg)	0.400	0.440	0.389	0.383
Total feed intake (kg)	16.02	16.84	14.41	15.06
Feed conversion ratio	1.41	1.38	1.33	1.44

Source: *Chalorklang et al., 2000a.*

Saesim *et* al. (1990) tested the effects of cassava diets and broken rice diets on the reproductive performances of breeder pigs. The trial was conducted at the farm for a period over one year. Sows on cassava diets had very similar reproductive performances to the sows on broken rice diets. It is clear that cassava can be an excellent source of energy feed ingredient in pig breeder diets (**Table 11**).

6.2 Broilers

Khajarern and Khajarern (1986) have demonstrated that cassava meal could be used as a sole source of energy feed ingredient comparable to maize, broken rice and sorghum in broiler diets **(Table 12)**. Broilers on cassava diets tend to have smaller body weights and poorer feed conversion ratios than those on the other diets but the differences were not significant.

Sriwattanaworachai *et al*. (1989) compared the effects of maize, sorghum and cassava diets on the performances of 4-7 week old broilers. The animals on cassava diets had slightly poorer weight gains and feed conversion ratios than those on maize and sorghum diets **(Table 13)**, but the differences were not significant.

Table 10. Effect of the substitution of maize by cassava meal in diets for growing-finishing pigs (30-100 kg) on their performance.

	Diet 1	Diet 2	Diet 3	Diet 4
Levels of substitution:	0	50%	75%	100%
Levels of cassava in diets (grow/finish):	0	25/28%	40/44%	53/60%
No. of animals	16	16	16	16
Initial weight (kg)	30.63	30.79	30.07	29.22
Final weight (kg)	99.50	98.22	101.03	101.71
Total weight gain (kg)	68.87	67.44	70.97	71.99
Average daily weight gain (kg)	0.773	0.813	0.818	0.812
Feed conversion ratio	3.03	3.11	3.16	3.16
No. of days tested	92	83	87	86
Dressing percentage	77.23	75.42	76.14	76.51
Lean percentage	42.97	42.96	44.17	42.50
Back-fat thickness (inch)	1.08	1.17	1.17	1.20

Source: *Chalorklang et al., 2000b.*

Table 11. Effect of the utilization of broken rice and cassava in diets for breeder pigs on their reproductive performance.

	Broken rice	Cassava
No. of litters	504	647
Farrowing percentage	93.16	88.19
Mummified+abnormal fetus (%)	1.91	1.64
Litter size at birth	9.25	10.02
Average birth weight (kg)	1.34	1.32
No. of lactating days	23.51	23.83
Litter size at weaning	8.09	8.23
Average weight at weaning (kg)	5.46	5.73

Source: *Saesim et al., 1990d.*

Table 12. Effect of the utilization of maize, broken rice, sorghum and cassava in diets for broilers on their performance.

	Maize	Broken rice	Sorghum	Cassava
No. of animals	140	140	140	140
Mortality (%)	2.14	2.14	2.80	2.86
Body weight at 8 weeks (kg)	1.70	1.68	1.70	1.64
Feed conversion ratio	2.27	2.27	2.30	2.39

Source : *Khajarern and Khajarern, 1986.*

Saentaweesuk *et al*. (2000a) studied the effects of substitution of maize by cassava in broiler diets and found that cassava can be substituted for 50% of the maize or at levels of 21%, 23% and 27% in broiler starter, grower and finisher rations, respectively, without any adverse effects on the performance of the animals. Higher levels of substitution led to a slightly but significantly ($P<0.05$) poorer weight gain and feed conversion ratio (**Table 14**). However, it is interesting to note that the trial was conducted in an open broiler housing of a small farmer during rather hot climate. Broilers on cassava diets (Diets 2, 3 and 4) were stronger, required much less medication and had lower mortality rates as compared to those on the maize diet (Diet 1). The meat of broilers on cassava diets (Diet 2, 3 and 4) had a better perception by consumers than those on the maize diets (Diet 1). The slightly slower growth of the animals and the minimal use of antibiotics may have improved the meat quality of broilers on the cassava diets.

Table 13. Effect of the utilization of maize , sorghum and cassava in diets for 4-7 week old broilers on their performance.

	Maize	Sorghum	Cassava
No. of animals	150	150	150
Initial weight (kg)	0.448	0.444	0.458
Final weight (kg)	1.92	1.93	1.85
Average weight gain (kg)	1.47	1.47	1.40
Feed consumed (kg)	3.41	3.51	3.38
Feed conversion ratio	2.32	2.36	2.42
Mortality (%)	0	2.0	0.67

Source : *Sriwattanawarachai et al., 1989.*

Table 14. Effect of the substitution of maize by cassava meal in diets for broilers (10–49 days) on their performance.

	Diet 1	**Diet 2**	**Diet 3**	**Diet 4**
Levels of substitution:	0	50%	75%	100%
Levels of cassava in diets[1)]	0	21/23/27%	31/35/42%	40/47/56%
No. of animals	400	400	400	400
Initial weight (g)	234.65	237.25	234.45	232.93
Final weight (g)	2,079.35[a]	2,003.26[a]	1,815.25[b]	1,846.00[b]
Mortality (%)	4.50	2.00	1.98	1.50
Total weight gain (kg)	1,844.70[a]	1,765.95[ab]	1,580.80[a]	1,613.06[bc]
Total feed consumed (kg)	3,745.22[a]	3,669.83[a]	3,449.45[b]	3,564.68[ab]
Feed conversion ratio	2.03[c]	2.08[bc]	2.19[ab]	2.21[a]

[1)] in starter/grower/finishing diets

Source: *Saentaweesuk et al., 2000a.*

Tathawan *et al*. (2002) found that broilers fed with cassava diets always had about half the mortality rate than those fed with maize diets (**Table 15**). Broilers on a cassava diet without antibiotics supplemention had significantly ($P<0.05$) lower mortality rate than those on a maize diet with antibiotics supplementation. It has been demonstrated that cassava diets have benefits on animal health and allow a minimal or no use of antibiotics in animal production. This advantage is also experienced by farmers and feed millers who have used cassava in animal diets in Thailand.

Table 15. Performances and mortality rate of broilers fed with maize or cassava diets, with or without supplementation with antibiotics.

Diets:	Maize	Maize	Cassava	Cassava
Antibiotics:	+	+	+	-
No. of chickens	198	198	198	198
Initial weight (kg/bird)	0.495	0.496	0.469	0.495
Final weight (kg/bird)	2.20	2.22	2.16	2.19
No. of days tested	28	28	28	28
Feed conversion ratio	1.86 [b]	1.92 [ab]	1.93 [ab]	2.00 [a]
Mortality (%)	8.79 [ab]	11.24 [a]	4.21 [b]	5.88[ab]

Source: *Tathawan et al., 2002.*

6.3 Layers

Khajarern and Khajarern (1986) have shown that cassava could be used as a sole source of energy feed ingredient in diets of pullets and layers when compared to maize, broken rice and sorghum (**Tables 16** and **17**). Pullets and layers on cassava diets had similar performances to those on maize, broken rice and sorghum diets. The animals on cassava diets had a low mortality rate and showed no signs of any toxicity of cassava in the diet.

Table 16. Effect of the utilization of maize, broken rice, sorghum and cassava in diets for pullets on their performance.

	Maize	Broken rice	Sorghum	Cassava
No. of animals	200	200	200	200
Mortality (%)	1.5	1.5	1.0	2.0
Body weight at 20 weeks (kg)	1.82	1.85	1.77	1.77
Feed conversion ratico	4.30	4.05	4.26	4.51

Source: *Khajarern and Khajarern, 1986*.

Table 17. Effect of the utilization of maize, broken rice , sorghum and cassava in diets for layers on their performance.

	Maize	Broken rice	Sorghum	Cassava
Laying percentage	66.22	72.90	62.06	69.56
Egg weight (g)	50.55	50.30	50.02	50.05
Yolk color score (NEAPA)	3.50	4.67	4.50	4.15
Feed consumed (kg)/dozen eggs	1.40	1.28	1.48	1.33
Mortality (%)	1/96	1/95	2/95	0/95

Source: *Khajarern and Khajarern, 1986.*

Saentaweesuk *et al.* (200b) studied the substitution of maize by cassava in diets for layers (22-37 weeks) (**Table 18**) and found that laying hens on 100% cassava diet (Diet 5) had similar production performances to those on 100% maize diets (Diets 1 and 2). Increasing the levels of cassava in the diets significantly ($P<0.5$) reduced the yolk color score. Diet 5, in which 100% of the maize was substituted by cassava, needed to be supplemented with 0.2% of marigold meal to provide adequate yolk pigmentation for local market acceptance. Cassava is an excellent energy feed ingredient for the production of pale yolk eggs for exportation.

Table 18. Substitution of maize cassava meal in diets for layers (22-37 weeks) on their performance.

	Diet 1	**Diet 2**	**Diet 3**	**Diet 4**	**Diet 5[1)]**
Levels of substitution:	0	0	50%	75%	100%
Levels of cassava in diets :	0	0	25%	36%	48%
No. of animals	576	576	576	576	575
Feed intake/hen/day (g)	114.7	115	113.6	112.8	112.4
Laying percentage	60.16	61.24	58.40	59.72	59.92
Mortality (%)	0.42	0.26	0.42	0.14	0.22
Average egg weight (g)	57.43	57.70	57.81	57.78	58.22
Yolk color score (Roche)	9.27[a]	9.40[a]	8.75[b]	8.36[b]	8.38[b]

[1)] Supplemented with 0.2% of marigold meal
Source: *Saentaweesuk et al., 2000b.*

6.4 Dairy cattle

Kanchanapreuttipong *et al.* (2000) studied the effects of substitution of maize by cassava in dairy concentrate rations. A total substitution of maize by cassava in the ration produced very similar milk yield and milk composition as those cows on the maize diets (**Table 19**). However, the percentage of feed cost/revenue was significantly reduced (P<0.5) when cows were fed the cassava diets. Cassava chips and pellets are ideal energy feed ingredients for beef and dairy cattle.

Table 19. Effect of substitution of maize by cassava chips in concentrate diets for dairy cattle on their performance.

Diets:	Maize	Maize + Cassava	Cassava
Levels of substitution :	100%	50%:50%	100%
Milk composition, % (kg/day)			
Butter fat	4.15 (0.80)	4.32 (0.85)	4.27 (0.83)
Milk protein	3.37 (0.65)	3.27 (0.64)	3.33 (0.65)
Lactose	4.97 (0.76)	4.93 (0.97)	4.96 (0.97)
Minerals	0.70 (0.13)	0.70 (0.14)	0.70 (0.14)
Solid non-fat	9.03 (1.74)	8.90 (1.75)	8.99 (1.75)
Total solids	13.19 (2.54)	13.23 (2.60)	13.26 (2.58)
Milk yield (kg/day)	19.23	19.64	19.44
Feed cost/revenue (%)	40.75[a]	34.33[ab]	28.17[b]

Source: *Kanchanapreuttipong et al., 2000.*

6.5 Aquaculture feed

Jintasataporn *et al*. (2000) evaluated the effects of substitution of maize by cassava in diets for hybrid catfish, and reported that the fish on 100% cassava (Diet 4) had similar production performances as those on 100% maize (Diet 1) **(Table 20)**.

Table 20. Effect of substitution of maize by cassava meal in diets for hybrid catfish on their performance.

	Diet 1	Diet 2	Diet 3	Diet 4
Levels of substitution:	0	50%	75%	100%
Levels of cassava in diets:	0	13%	20%	26%
Total weight gain (g/fish)	84.06	82.96	80.46	98.80
Average daily weight gain	0.70	0.69	0.67	0.82
Total feed consumed (g/fish)	144	115	147	176
Feed conversion ratio	1.72	1.36	1.83	1.79
Survival rate (%)	88.6	90.3	86.1	98.9

Source: *Jintasataporn et al., 2000.*

It can be concluded that cassava can be used as a sole source of energy feed ingredient in every kind of animal ration, including pigs, poultry, ruminants and aquaculture feeds. The inclusion rate of cassava in the animal rations are summarized in **Table 21**. However, care should be taken on the use of cassava for broiler rations, since fowls are sensitive to bulkiness and to the fiber contents of the feed; therefore, cassava is recommended to replace only 50% of maize (25-30% inclusion of cassava) in broiler diets.

Table 21. Recommended maximum inclusion levels of cassava meal in the feed rations of various animals.

Animal rations	Max. inclusion levels (%)
Pigs (weaners, grower, finisher, breeder)	40 - 60
Broilers	25 - 30
Layer hens	40 - 45
Ducks (meat and layers, breeders)	40 - 45
Beef and dairy cattle	35 - 40
Aquaculture	30 - 35

Note: Cassava has also been successfully used as a maize substitute in rabbit and horse feeds.

7. Practical Experiences in Using Cassava in Animal Feed Rations in Thailand

Cassava has been promoted as a replacement for maize in pig, poultry and ruminant diets in Thailand for more than 15 years. Initially only a limited number of farmers adopted and practiced the technology, but the results were very successful. Extensive use of cassava in animal rations has been practiced since 1997 when both the animal production and the feed industries were severely affected by the economic crisis. The devaluation of the Thai currency had resulted in an increase in feed costs and the cost of animal production while the local market prices of feed ingredients were reduced. In contrast, the exported price of cassava to the EU was also reduced due to the reduction of agricultural subsidies in the EU countries. The use of cassava in domestic animal diets was therefore the solution to various problems.

Cassava has been actively promoted for use in animal diets by the Animal Nutrition Research and Development Center (ANRDC), Kasetsart University, Kampaengsaen, Nakhon Pathom with a research grant from the Thai Tapioca Development Institute (TTDI). Seminars and workshops on the utilization of cassava in combination with soybean meal in animal rations have been conducted repeatedly in various parts of Thailand. Books and a video on the utilization of cassava and soybean meal in animal rations have been prepared and distributed to the farmers. Follow-up evaluations need to be conducted in order to correct the field problems and to ensure the success of the project. In addition, improvement of the quality of cassava chips produced in Thailand has been promoted in order to satisfy the requirement of the animal industry. Good quality cassava chips and pellets, which are key factors for the successful use of cassava in animal diets, are increasingly available in the country and are helping to increase the acceptance of cassava in the feed industry. To date cassava has been extensively accepted in animal feed rations in Thailand, including for growing-finishing, breeder and weaned pigs, layer hens and ducks, meat-type ducks, and dairy and beef cattle, with successful results and satisfaction to the farmers.

Cassava is an appropriate feed ingredient for pigs, ducks and cattle because these animals can tolerate high levels of dietary crude fiber and require no pigmentation in the diets (except for laying ducks). Acceptance of using cassava in animal feed rations is now widespread among farmers, ranging from small farmers (10-20 sows unit) to large commercial farmers (over 10,000 sows unit) with rather equally successful results. It is worthy to note that most of the farmers are satisfied with the following advantages of using cassava in their animal rations.

1. Satisfactory animal performances and carcass quality while the feed cost and animal production cost are reduced.
2. Reduction of medication and antibiotics used in animal production, and the improvement of animal health induced by cassava diets.
3. Reduction of the fetid smell of the manure and reduction of environmental pollution.

In many occasions when there were no differences in the prices between maize and cassava diets, a number of farmers still maintained the use of cassava in animal rations due to the advantages of animal health improvement and less smell and pollution as a result of the cassava diets. A number of pig and poultry (broiler) farms have used cassava as their main feed ingredient in the diets for production of antibiotics-free pork and poultry meat.

8. Advantages of Using Cassava in Animal Diets

The results of the past studies and the practical field trials have indicated that good-quality cassava has the following advantages in animal nutrition:

8.1 Comparable performance but higher quality of animal products than maize diet

Good-quality cassava with proper nutritional balance, obtained by good diet processing, has produced very comparable production performances of the animals as compared to those on cereal diets. But farmers always reported that cassava diets produced better quality animal products including meat, milk and eggs. Although no scientific explanation can be made, the favorable results may be due to less stress situation for animals on cassava diets.

8.2 Higher digestible starch

The starch in cassava is a very soft starch, which is more readily gelatinized and digested in the digestive tract of the animals as compared to cereal starches. Highly digestible starch create less stress to the animals and stimulate more growth of nonpathogenic microorganisms which will produce more acidic conditions and suppress the growth of pathogenic microorganisms in the digestive tract.

8.3 Minimum or no mycotoxins contamination

It has been shown that cassava products contain minimal or no mycotoxins, including aflatoxins, when compared to cereals, especially maize. Cassava has been successfully fed to breeder animals and ducks which are very sensitive to mycotoxin toxicities, expecially zearalenone and aflatoxins. Apparently, no aflotoxicosis or toxicity of other mycotoxins have been reported by the farmers who have employed cassava in animal diets for many years. Aflatoxin is a powerful stressor in animal diets, which not only reduces the performance of animals, especially their feed conversion ratio, but also impairs immunity production and causes more illness in the animals. Modern high-performance animals always are more sensitive to stress including aflatoxins in the diets. The animals, therefore, require feeds which are not only nutritionally balanced and highly digestible but also contain no or very low levels of toxic substances which cause stress to the animals. Cassava is an ideal feed ingredient meeting this requirement.

8.4 Animal health improvement and "green" food production

Animals on cassava diets always have better health and require less or no antibiotics during production, compared to animals on cereals, especially on maize diets. The highly digestible starch and minimal aflatoxin contamination could be responsible for this advantage. Cassava diets can therefore provide "green" meat or "green" food production which is an important consideration for animal production in this new millennium.

8.5 Minimum animal waste odor

Practical field trials have shown that manure or feces of animals on cassava diets produce less fetid smell or have less odor than those on cereal diets. Although the exact reasons are not known, the advantage helps to reduce the pollution problems of animal production units.

8.6 Non-GMO feed ingredient

Cassava varieties grown in Thailand have been produced through traditional breeding methodologies and are certified to be non-GMO. Cassava products can therefore be used in animal production for export, especially to EU countries.

8.7 Reduction of animal production costs

Cassava diets lower the cost of animal production, not only by the reduction of feed cost but also by the reduction or elimination of the use of antibiotics and medication in animal production. This advantage is an important factor for farmer acceptance, and for more utilization of cassava in animal diets in Thailand and in the rest of the world.

9. Key Factors For Successful Use of Cassava in Animal Feed Rations

Although cassava is an energy feed ingredient comparable to maize, cassava has many other characteristics that affect its utilization in animal diets. It is therefore necessary to have a thorough understanding of cassava in order to successfully use the ingredient in animal rations.

9.1 Production of good quality cassava chips and pellets

Only good quality cassava which has the following specification is recommended for inclusion in animal diets:

Moisture content	max.	14%
Crude protein content	min.	1.5-2.0%
Crude fiber content	max.	3.50-4.00%
Ash content	max.	2.00%

The above cassava products will contain 75-80% nitrogen-free extract and give very good results for animal feeding. Cassava chips that have minimal or no stem or woody parts will have crude fiber levels below this limit. High levels of sand or soil contamination will increase the ash content in the cassava products. The products should be dried for at least 3-6 days and should be stored for at least 5-6 days before being included in animal rations. Cassava products should be clean and have no visible mold growth. With enough experience, one can estimate the starch content by breaking a piece off dry cassava chip.

9.2 Feed formulation

Cassava diets should be balanced for protein and essential amino acids according to the requirement of each type of animals. Weight by weight substitution of cassava for maize in animal diets will lead to lower protein and amino acids contents of the diet and cause poor growth, poor feed conversion ratios, poor carcass quality and poor productivity of the animals. More soybean meal or extruded full-fat soybean need to be added when employing cassava diets. Cassava-soybean diets with a proper balance of amino acids have been used successfully by pig farmers in Thailand.

9.3. Grinding and reduction of dustiness

Cassava chips are very bulky and contain soft starch. Grinding of cassava chips is always very dusty and causes severe air pollution in the feed mill. Dust collection units of either the cyclone dust collector with filter bags or the automatic filter bag dust collector is required to prevent spreading the dust into the atmosphere. Ground cassava is still very dusty and always reduces the feed intake of animals raised on mashed cassava diets. Dusty feed will stimulate animals to drink more water which impairs feed intake and causes growth depression of the animals. Addition of 4-5% molasses in the diet is recommended in order to eliminate the dustiness of the feed. High levels of fat addition in the diets would decrease the levels of molasses required for dust control in mashed cassava diets. Pelleted feed or wet feed give no problems of dust and do not need molasses addition in the formula.

9.4 Body fat adjustment

Cassava diets may contain very low fat and may cause hard fat accumulation in the animal body. In countries where hard carcass fat is avoided, it is advisable that cassava diets contain at least 3% of soft–fat in order to correct the fat condition in the animal. High-fat feed ingredients such as rice bran, extruded full-fat soybean or rice bran oil are recommended to be included in the cassava diets.

9.5 Yolk and skin color of poultry

Cassava contains no pigment and the diet may cause pale egg yolk and pale skin of the poultry. Cassava diets may have to be supplemented with sources of pigment such as leucaena leaf meal, marigold meal or synthetic pigments in order to color the yolk and skin according to the requirements of the consumers. The required supplementation is approximately 30 mg of xanthophyl/kg of diet.

10. National Program on Cassava Chips and Pellets Quality Improvement and Quality Assurance in Thailand

Good quality cassava is an important factor for the successful use of cassava in animal diets. The government of Thailand is therefore launching a national program on the promotion of good quality cassava chips and pellets production in the country, both for domestic use and for export. Good quality cassava chips should conform to the following standard :

Moisture	max.	14%
Crude fiber	max.	3.5-4.0%
Sand/ash	max.	2.0%
Starch (NFE)	min.	75-80%

Cassava products containing minimal levels of crude fiber and sand/ash will be good substitutes for cereals in animal diets. Governmental offices and organizations related to cassava production, utilization and trading are involved in the program and carry out the following activities:

10.1 Department of Foreign Trade (DFT), Ministry of Commerce

DFT is providing a total of 120 million baht in soft loans to 300 commercial cassava chips/pellets processors for installation of sand sifters into the production process, which will reduce the content of sand in the cassava products to less than 2%. The processors also need to reduce the fiber content of the cassava products to less than 3.50-4.00%. DFT, together with ANRDC and TTDI, will test, monitor and certify processors who consistently produce good quality cassava chips according to the above standard. The project aims to produce a minimum of 3 million tonnes of good quality cassava chips annually.

10.2 Department of Cooperative Promotion (DCP), Ministry of Agriculture and Cooperatives

DCP is providing a total of 426 million baht in soft loans to 60 agricultural cooperatives who grow and process good quality cassava chips. The cooperatives may be directly involved in the production of good quality cassava chips, or in collection of good quality cassava chips produced by the members or villagers, and market these to the users. Cassava growers (farmers) are encouraged to partly process the fresh roots for good quality cassava chips which will produce an additional income to the families. Cassava chips produced by these farmers or villagers are always of high quality and are in great demand by the animal farms and feed mills. DCP and ANRDC will continuously and regularly test, monitor and certify the cooperatives who consistently produce good quality cassava chips according to the standard. The project will produce approximately 300,000-500,000 tonnes of good quality cassava chips annually for domestic consumption and for export.

10.3 Animal Nutrition Research and Development Center (ANRDC), Kasetsart University, and the Thai Tapioca Development Institute (TTDI)

ANRDC and TTDI have been pioneers in promoting the production of clean and good quality cassava chips for the animal feed industry in Thailand since 1998. A number of cassava processors, ranging from small villagers to large commercial processors, have joined the project and have improved the quality of cassava chips for the animal feed industry in the country. The project not only has demonstrated the benefit of high-quality cassava for animal feeding to the farmers, but has also provided assurances for the future production of good-quality cassava for the animal feed industry. ANRDC and TTDI have not only provided training and supervision in techniques and practices in the production of good quality cassava chips but have also tested and monitored the quality of the products produced, by direct sampling from the processors and by analyzing samples sent by the customers. Good processors, which consistently produce good quality products, are publicized directly to the farmers and to the feed industry.

ANRDC and TTDI will continue their activities in promoting the greater utilization of good quality cassava for animal feeds. Seminars and workshop on utilization of cassava in animal nutrition are conducted throughout the country. More research on the beneficial effects of cassava diets on the health of animals is being conducted. The results of recent advances in using cassava in animal diets and the names of certified cassava processors are publicized via www. tapiocafeed.com.

10.4 Office of Industrial Standard (OIS), Ministry of Industry, and Department of Livestock Development (DLD), Ministry of Agriculture and Co-operatives

OIS and DLD, which are authorized organizations to certify the standard of manufacturing practices and the standard quality of industrial products including animal feeds, have planned to improve cassava pellet production practices and to certify GMP and HACCP to processors who meet the standard. The certifications are essential for export of cassava products to the EU. Cassava pellet processors and exporters will be trained and monitored, and improvements will be made in the production process until the standards are met and certification can be provided. The activity is expected to be completed before December 31, 2001.

The government of Thailand expects that these national programs will result in an increase in the production of high quality cassava products, in increasing the use of cassava in animal feed in the country and in increasing the export of cassava products to the EU and other countries. The programs will also provide a sustainable marketing strategy and practice for the cassava industry in Thailand.

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