A New Future for Cassava in Asia:

Its Use as Food, Feed and Fuel to benefit the Poor

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HARMONIZING THE SUPPLY OF CASSAVA TO MEET THE INCREASING DEMAND FOR FOOD AND VARIOUS OTHER USES IN INDONESIA

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ABSTRACT

During the past 40 years the cassava harvested area in Indonesia has declined from 1.5 to 1.3 million ha, but cassava yields have significantly increased from 7.5 to 15.5 t/ha. Therefore, total production has increased from 11.3 to 19.6 million tonnes. However, the increase in production is still not able to meet the rapidly increasing demand. Previously, the demand for cassava was primarily for human consumption as well as for export as dry chips for animal feed to European countries and Japan. The greater domestic demand for starch and starch-derived products, such as sorbitol, maltose, glucose and fructose syrup, has required the importation of starch from Thailand. Various food products made from fresh roots, dried flour as well as starch also contributed to the increased demand. Recently, the growth of the renewable fuel industries (ethanol) for domestic use and export (China, Korea and Japan) also require huge amounts of raw material in the form of fresh roots or dried chips. Consequently, the resulting increase in the price of fresh cassava roots has benefited many farmers who had never experienced this previously.

To meet the greater demand, the yield level of cassava has to be increased substantially. On the other hand, expanding the planting area is also an appropriate solution. However, the expansion of the cassava area should avoid the logging and destruction of forested areas. Instead, grasslands or unused land that was previously in forest could be used to cultivate cassava under an agroforestry system. Intercropping cassava with associated crops such as cereals and grain legumes should be undertaken more widely in attempts to achieve greater harmony in cassava development programs. Applying better crop and soil management practices is a must for achieving a better image of cassava development in harmony with economic and ecological considerations.

Keywords: cassava, Indonesia, supply, demand.

INTRODUCTION

Cassava is not a native crop of Indonesia; it was introduced during the early colonial era after Columbus found the new world "America". The introduction of cassava into Indonesia occurred around the middle of the 18th century, entering through Maluku (Cock, 1985). From the Maluku islands cassava was distributed throughout the other islands of Indonesia, including Java. During the Mataram Kingdom cassava was propagated in Pogung Raharjo in Sleman, Yogyakarta, and was distributed throughout the island of Java (1880-1920); therefore, in East Java cassava is also known as Pogung. In the early 20th century cassava started to be used for large-scale cultivation for the export of dried peel for animal feeding in Europe by the Dutch government in Indonesia. During the First World War and thereafter, cassava was able to safe people in Java living nearby cassava plantations from famine. From that experience, in the mid 20th century the cultivation of cassava in Java was progressively developed for use as food, for the starch industry and for export. From the early 20th century (1905), as part of the first transmigration program, cassava was distributed to 105 households from Central Java to take to Lampung on Sumatra island. Furthermore, in conjunction with the transmigration

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program, cassava was recognized as having greater adaptability to various sub-optimal conditions, and was thus distributed from Java throughout the country (Widodo, 1993).

During the early days of independence in the early fifties (1945-1955) cassava was again able to reduce a severe famine due to post-Second World War and internal conflicts caused by an unstable political situation. Since cassava was frequently saving people from hunger, and has flexibility of storage in the form of dried peeled chunks, called *gaplek*, Mr. Mukibat, a farmer in Ngadiluwih, Kediri, tried to improve its productivity by grafting the wild cassava (*Manihot glaziovii*) on top of ordinary cassava (*Manihot esculenta*). In the beginning, this grafting method of cassava was intended to avoid stealing due to food insufficiency. After harvesting the grafted cassava, Mr. Mukibat and family were very surprised to see a 5-10 fold yield increase over ordinary cassava. After that, the Mukibat method was quickly disseminated. During the 1960s the Mukibat method was an effective way to produce more food from the starchy roots of cassava in order to reduce food shortages.

In line with the green revolution in cereal production by introducing early maturing rice varieties, the cassava Mukibat system was able to increase food production significantly. By the intensive management of the cassava Mukibat system in home gardens cassava could produce more than 50 kg/individual plant/year. In addition, by implementing the Mukibat system and growing cassava in home gardens the roots could be harvested piecemeal. Cassava could thus be harvested over a longer period (>2 years). Unlike ordinary cassava, which had to be harvested at the end of the dry season and then processed into a dried form to be stored, the Mukibat cassava could be kept in a fresh form in the field and harvested when required.

Widodo (1986) reported that the cassava planted area decreased significantly due to the conversion of uplands, cassava’s domain, into irrigated areas for lowland rice. Consequently, to satisfy the demand, which tended to increase, cassava planting moved into dry marginal and more risk-prone areas. By the 1970s the expansion of cassava outside of Java developed progressively, especially in order to meet the increasing demand from the starch industry. Entering the third millennium, the demand for cassava tended to increase, even though the harvested area tended to stagnate or even decline. Recently, due to the lower availability and the incredibly high price of fossil fuels, the use of cassava as a raw material for production of bio-fuel (ethanol) is being promoted, as it is considered more ecologically friendly, and is a renewable source of energy. Therefore, a higher level of productivity of cassava, as well as the expansion into other appropriate regions, is urgently required. Significant simultaneous increases in yield and in the harvested area will contribute to a boost in the national production (**Table 1**). If this occurs, then there will be no conflict between the demand for food, feed, the existing processing industries and for bio-fuel.

INCREASING DEMAND

The initial move of cassava cultivation from Maluku to Java was meant for large-scale plantations to meet the demand for feedstuff in Europe. This coincided with a period of food scarcity, which forced poor farmers in Java to use cassava as a source of carbohydrate food. The plantation of cassava during the Dutch colonial period emphasized the use of bitter cassava with an HCN content of >100 ppm. From the beginning the export of cassava to the European market was aimed to fulfill the demand for animal feed, so shipping in the dried form of *gaplek* was considered sufficient. Processing cassava into *gaplek* was very simple: by peeling the skin and cutting the roots into smaller pieces, these would dry faster during sun-drying. This simple way of preparation could be done directly by farmers. It seems that the method to prepare *gaplek* was taught by the Dutch to farmers in Java in order to fulfill the market demand for *gaplek* in Europe.

Table 1. Trend in cassava area, yield and production in Indonesia during the past 40 years.

Years	Harvest area (ha)	Yield (t/ha)	Production (tonnes)
1968	1,503.000	7.56	11,356,000
1973	1,429.000	7.80	11,186,000
1978	1,383.000	9.30	12,902,000
1983	1,221.000	9.90	12,100,000
1988	1,303.000	11.87	15,471,000
1993	1,401.600	12.30	17,285,400
1998	1,205.400	12.20	14,696,200
2003	1,244.500	14.90	18,523,800
2008*	1,341.607	15.50	20,794,607

Source: *BPS 1970-2006; *www/bps.go.id*

The production of *gaplek* by farmers who chronically suffered from food scarcity, stimulated people to prepare a palatable food from a dirty raw material (during the processing of *gaplek* the peeled roots were sun dried directly on the soil). Unlike fresh cassava that will easily deteriorate in around 3-4 days, cassava in the form of *gaplek* could be stored for up to 12 months to secure against food insufficiency. From *gaplek* several food preparations could be made. The most common food preparation that is still widely practiced by rural households is *tiwul*, which is a staple food other than rice for low-income communities. *Tiwul* is processed from *gaplek* flour. Processing *tiwul* is as follows: flour of *gaplek* is mixed with hot water which will form granules when the mixture is swirled on a bamboo tray; these granules are steamed for about 15-20 minutes. *Tiwul* is the most popular staple food derived from *gaplek*. It can be consumed directly after cooking or is dried as a storable instant *tiwul* (Gintine *et al*., 1989a). *Tiwul* is eaten like rice, with several side dishes to meet the local taste. Instant *tiwul* is a popular food, not only for the poor but also for middle-income communities.

Other than *tiwul*, there is a dish called *gatot* that is prepared from *gaplek*; its preparation is faster than that of *tiwul*. *Gatot* can be prepared by soaking *gaplek* in water for more than six hours to make it soft; these are then sliced into small pieces and steamed. Unlike *tiwul* which is a staple food, *gatot* is only used as an additional snack, mostly eaten with shredded coconut. *Tiwul* can also be used as a snack, by mixing in palm sugar during preparation, and then mixing this with shredded coconut to improve the taste. Fermented food could be generated not only from fresh cassava, but also from *gaplek*. However, the best quality fermented food from cassava is made from fresh cassava without any physical or microbial deterioration. On the contrary, during the drying process *gaplek* suffers some physical deterioration. Therefore, fermented products made from *gaplek* are not as attractive as compared to those made from fresh cassava, especially with respect to color.

The color of fermented fresh cassava can be white or yellow, depending on the original color of the flesh in the fresh form. But, fermented food made from *gaplek* has a color that looks dirty, grey, brown to dark (blackish). Because of this, there is an increasing demand for products made from fresh cassava instead of *gaplek.* Improvements in the processing of traditional foods, as well as recent innovations in making new products from cassava, have made cassava-based products very popular due to the lower price of cassava, either fresh or as *gaplek*, as compared to other raw materials used in food processing, such as wheat, rice, maize etc.

Table 2. Quality standard of dried cassava (*gaplek*) in Indonesia based on SNI No. 01.2905-1992.

	Categories			
Parameters	Super Quality	Quality I	Quality II	Quality III
Water content (% w/w maximum)	14	14	14	14
Starch content (% w/w maximum)	70	68	65	62
Fiber content (% w/w maximum)	4	5	5	5
Sand content/silica (% b/b maximum)	2	3	3	3

w/w = weight/weight

During the Dutch colonial period, when cassava was used mainly for export to Europe in the early 20th century, it was estimated that 90% of total production was exported, and the remaining 10% was used for local consumption. Due to the famines caused by the First and Second World War the proportion of cassava for domestic consumption increased. In the early days of independence (1945-1968) Indonesia was the largest exporter of cassava in the world. But, after 1968 this position was taken over by Thailand. However, as cassava production decreased due to the conversion of uplands into irrigated lowland areas for rice, demand for cassava remained high. This demand was mainly satisfied by an increase in productivity, from 7.56 t/ha in 1968 to 8.71 t/ha in 1988, and to 15.6 t/ha in 2008. Consequently, this increase in productivity contributed to a marked increase in production which is currently over 20 million tonnes per year.

In 2003 about 47% of cassava production was used for food, 2% for feed and 38% for “other” uses, which includes processing into non-food products. The remaining 13% is listed as “waste”, such as peel and solid residues from processing, which are mostly used for animal feeding (FAOSTAT, 2010). The apparent consumption level of cassava was about 41 kg/capita/year (FAOSTAT, 2010), the highest level in Asia except for East Timor. The consumption level of cassava in rural areas was 4-5 times higher relative to urban areas (Setyono *et al*., 1992). According to ICBS (1999), about 6% of households in rural areas consumed roots (predominantly cassava) every day and 21% two to five times per week; in urban areas this was 2% and 16%, respectively. Cassava is consumed either as a staple food or in the form of various snacks. As snacks, the fresh roots are generally boiled or steamed, deep-fried or fermented to prepare various types of foods, such as *ubi rebus, ubi goreng, getuk, tape, lemet* and *keripik*. There are at least 90 different kinds of traditional foods that can be prepared from fresh cassava (Setyono *et al.,* 1992). These traditional foods are popular in both rural and urban areas; however, more different types of snacks are found in rural areas.

In addition to direct consumption, cassava can also be processed into intermediate products, such as *gaplek*, starch and flour (**Figure 1**). Starch is mainly produced for commercial purposes, both for food (*kerupuk* or cracker, sweeteners, thickener, filler, binder or stabilizer) and non-food industries (sorbitol, maltose, glucose, mono-sodium glutamate and other chemical products, for paper, textile, pharmaceuticals etc.) (Setyono *et al*., 1992). Starch is extracted from the roots with water. This process requires a lot of water. Therefore, the starch industry can only be developed in those areas where water is easily available. Widodo (1993) reported that Lampung province could supply only about 60% of the raw material required for the starch industries in the province. Moreover, Widodo (1993) and Widodo and Hartojo (2001) concluded that the huge amount of water (8,000 l for 1 t of fresh cassava roots) required for the extraction process in the starch factories was an environmental problem. In fact, starch production has great prospects, but the effects on the environment should be well-managed. Widodo and Hartojo (2001) concluded that to be ecologically, economically and socially friendly the large-scale starch industry should be spread over a wider geographical area. It does not mean that the big starch factories should be immediately stopped. But, stronger environmental regulation for building new large-scale starch factories should be considered. The building of smaller scale factories may be another alternative.

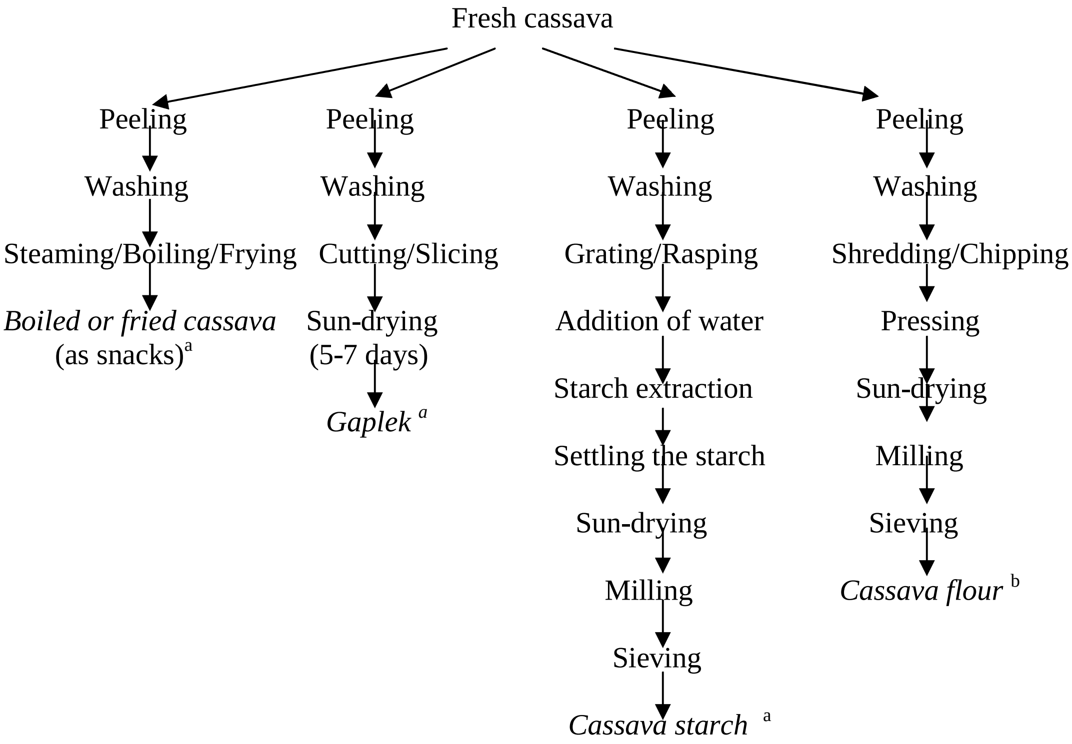

Figure 1. Flow chart for the preparation of cassava snacks, gaplek, starch and flour.
***Source**: [a] Barret and Damardjati, 1984; [b] Damardjati et al., 1996.*

The Cassava Starch Industry and its Consequences

Widodo (1993) reported that the fish and shrimp ponds on the eastern coast of Lampung province were polluted by waste water from the cassava starch industry. This was particularly due to the poor waste management in the large-scale cassava starch factories. Commonly, the liquid waste from the starch extraction process was released directly into the rivers and ended up down-stream in fishery ponds. Currently, about 25% of the fresh cassava roots produced nationally is required as raw material for starch processing. It means that almost 5 million tonnes of fresh roots are processed into starch. The starch industry generally uses the more bitter, high (>100 ppm) hydrogen cyanide (HCN) cassava cultivars. In the starch extraction process the HCN is released and part of it may end up in the waste water. In terms of food safety, the natural presence of cyanogenic glucosides in cassava roots is of concern because of their potential toxicity. The amounts of HCN, a highly toxic compound, produced after the release of cyanogenic glucosides varies in different cultivars from 1 up to 1000 mg/kg (Bradbury, 1990). Cassava roots containing <50 mg HCN/kg fresh roots are considered "sweet" cultivars, while the "bitter" cultivars have >50 mg HCN/kg. Cassava roots with >100 mg HCN/kg are not safe for direct consumption as it may cause acute poisoning and death (Coursey, 1973, *in* Richana and Suarni, 1990). Therefore, the sweet cultivars are mostly used for fresh consumption of cassava roots. However, the bitter cultivars, with relatively high HCN content, tend to have higher yield potential and starch contents (Setyono *et al*., 1992; Ginting *et al.*, 1999). These characteristics are desired by starch and flour processors as well as by most farmers. On the other hand, different processing methods of cassava roots result in different levels of cyanide reduction (Coursey, 1973, *in* Bradbury, 1990). Hence, the use of cassava roots for food should combine effective processing methods to reduce the HCN content with the selection of cultivars with high yield potential and low cyanide content.

Cyanide Toxicity: Warning in Food Safety

Although cassava was introduced to Asia almost four centuries ago, accidents resulting in human death due to cyanide toxicity still occur, particularly during famines. There are two cyanogenic glucosides present in cassava roots, namely linamarin, which accounts for 95% of the total cyanogen content, and lotaustralin (Balagopalan *et al.*, 1988, *in* White, 1994). The hydrolysis of linamarin by the β-glucosidase and linamarase (at optimum pH of 5-6), results in the production of acetone cyanohydrin. This can be further decomposed to free-cyanide (HCN) and acetone, either spontaneously or enzymatically by hydroxynitrile lyase at pH greater than 4.0 (optimum pH is 5.0) and temperatures greater than 30°C (White *et al.*, 1994). HCN, which is known to be highly toxic, is volatile with a boiling point of 25.7°C (Nweke and Bokanga, 1994) and is also soluble in water (Oke, 1994). Liberation of free cyanide only occurs from tissues that are physically damaged by crushing or maceration during processing, indicating that the enzymes and the substrate are located in different compartments in the cell (White *et al.*, 1994). Information on the conditions required for such chemical and biochemical changes are important in enhancing HCN reduction during processing.

The lethal dose of cyanide was reported to be 0.5-3.5 mg HCN/kg body weight. The human body is able to detoxify as high as 100 mg of HCN in 24 hours by rapid conversion of cyanide to the much less toxic thiocyanate (Montgomery, 1980 *in* Bradbury, 1990). However, high levels of cyanide ingestion may cause acute cyanide intoxication, which particularly may occur in cassava-eating populations due to the consumption of food in which removal of HCN was insufficient during cooking. The predominant symptoms include nausea, vomiting, dizziness, weakness and sometimes collapse, which occasionally leads to death (Rosling, 1994). The conversion of cyanide to thiocyanate uses the sulfur-containing amino acids, cystein and methionine; hence, consumption of low protein foods, which is a common situation in cassava eating populations, would enhance the toxic effects (Rosling, 1994).

Table 3. Quality standard of cassava starch[1)] (SNI, 1994) and flour[2)] (SNI, 1996) in Indonesia.

Quality Standard	Starch/Tapioca Quality I	 Quality II	 Quality III	Cassava flour
Water content (% w/w maximum)	15	15	15	12
Starch content (% w/w minimum)	-	-	-	75
Ash content (% w/w maximum)	0.6	0.6	0.6	1.5
Fiber and others (% w/w maximum)	0.6	0.6	0.6	4
Acidity (ml 1N NaOH/100 g, maximum)	3	3	3	3
HCN content (ppm, maximum)	-	-	-	40
Whiteness (%) ($BaSO_4$ = 100%)	min. 94.5	min. 92.0	< 92.0	min. 85
Viscosity (^{o} Engler)	3 – 4	2.5 – 3	< 2.5	-
Smoothness (screening 80 mesh) (%)	-	-	-	min.90
Heavy metal *:				
- Pb (mg/kg, maximum)	1.0	1.0	1.0	1.0
- Cu (mg/kg, maximum)	10.0	10.0	10.0	10.0
- Zn (mg/kg, maximum)	40.0	40.0	40.0	40.0
- Hg (mg/kg, maximum)	0.05	0.05	0.05	0.05
- As* (mg/kg, maximum)	0.5	0.5	0.5	0.5
Microbial contaminants*:				
- Total plate count (colony/g, maximum)	1.0×10^6	1.0×10^6	1.0×10^6	1.0×10^6
- *E. coli* (APM/g)	10	10	10	< 3
- Yeast/fungi (colony/g, maximum)	1.0×10^4	1.0×10^4	1.0×10^4	1.0×10^4
Added chemicals (sodium bisulfite)	-	-	-	as standard SNI 010222-1995
Characteristic:				
- Odor	-	-	-	Specific
- Flavor	-	-	-	Specific
- Color	-	-	-	White
Other substances	-	-	-	None

w/w=weight/weight * used especially for food.
***Source**: 1) SNI, 1994,; 2) SNI, 1996.*

Thiocyanate has been observed to be a potential goitrogenic agent that may aggravate iodine deficiency, resulting in goiter, the enlargement of the thyroid gland, and cretinism, a severe form of mental retardation (Bokanga *et al.*, 1990). These conditions are not solely caused by an overload of thiocyanate in the human body due to long ingestion of cyanide, but are also caused by low intake of dietary iodine (Delange *et al.*, 1994).

Long-term ingestion of cyanide from cassava may also cause neurological disorders, such as tropical ataxic neurophathy, that usually occurs among adult males and results in an uncoordinated gait, called ataxic, as well as epidemic spartic paraparesis, a spastic paralysis of both legs that mainly affects women and children (Rosling, 1987 *in* Bradbury, 1990). Above facts show that cassava-related disorders are often related to food insecurity, agro-ecological crises and severe social economic circumstances. In addition, the safe limit has not been set for individual cyanogens that might be present in cassava products. HCN is always present in small amounts due to its volatility; hence, the presence of linamarin and its intermediate product, cyanohydrins, may further act as the main sources of dietary cyanide. Banea *et al.* (1995) found negligible amounts of HCN in the stiff porridge derived from cassava flour, whereas cyanogenic glucosides and cyanohydrins remained. Studies in animals showed that linamarin may break down, resulting in HCN in the gut if suitable glucosidases are present in the gut microflora. It can also be absorbed and excreted unchanged in the urine. Cyanohydrins yield cyanide rapidly in the alkaline environment found in the small intestine (Cook *et al.*, 1982, *in* Banea *et al.*, 1995). These cyanogens may also become toxic as well; hence, establishment of the safe levels for consumption of these cyanogens consumption seems to be warranted.

Table 4. Chemical and physical properties of cassava flour and two cassava-based composite flours.

Criteria	Cassava flour*	Cassava composite flour **	
		A	B
Water content (%)	11.11	9.91	10.28
Carbohydrate (%)	84.64	78.73	78.27
Protein (%)	1.65	9.08	8.89
Fat (%)	0.65	0.53	0.63
Ash (%)	1.50	1.75	1.93
Fibre (%)	1.63	-	-
Amylose (%)	22.68	23.51	23.14
Gel consistency (mm)	38.67	52.00	51.30
Water absorption value	172.78	89.13	103.12
Water dilution value	7.45	1.10	1.13

Note : A = 60% cassava flour + 20% mungbean flour + 20% wheat flour
B = 60% cassava flour + 20% pigeon pea flour + 20% wheat flour

Source : **) Marzempi, 1995; **) Richana dan Damardjati, 1990.*

The safe level for consumption of cassava products has been established as low as 10 mg HCN equivalent per kg dry weight by the Codex Alimentarius of FAO/WHO (1988) *in* Rosling (1994). This level would allow consumers to have an intake of 5 mg in 24 hours. However, Rosling (1988) as quoted in Lynam (1994) estimated that ingestion of 5-100 mg HCN per 24 hours was still safe even at low levels of protein intake, and ingestion of >100 mg can be detoxified under normal dietary intake by adult subjects. The upper level for cassava for breeding purposes was set at a level 30 times higher (100 mg HCN/kg fresh weight or approximately 300 mg HCN/kg dry weight) than the established safe level, probably taking into account the HCN removal during processing prior to consumption. This suggests that the set safe level may actually be too low, and a higher level as cut-off point may need to be established. The safe level should be based on cyanide detoxification rates in humans with a necessary safety margin for natural toxins, degree of cyanide release from ingested cyanogens, expected daily consumption and degree of cyanogens removal during processing (Rosling, 1994).

Cyanide Pollution from the Starch Industry

Several processing techniques show different levels of cyanide reduction in cassava root products. Activities like crushing or physically damaging the root tissues, using large amounts of water and dehydration, which are normally involved during processing, result in the enzymetic break-down of the cyanogenic glucosides to cyanohydrins, followed by degradation of the cyanohydrins to HCN. HCN will readily disappear due to its volatility and rapid disolution in water (Nambisan and Sundaresam, 1985). According to Richana and Suarni (1990), soaking of peeled cassava roots in water (1:3 w/v) for 20 hours reduced the HCN content about 37%. This level was found to be higher (50%) for the bitter varieties relative to the sweet varieties (25%). Subsequent drying of the soaked roots to obtain *gaplek*, followed by milling into flour resulted in a still higher cyanide reduction level of 70%, and up to 81% for the bitter varieties. The HCN content found in *gaplek* and cassava flour was below 50 mg/kg (dry basis), suggesting that soaking and drying are efficient methods to reduce the HCN content. In addition, shredding of peeled cassava roots and subsequently pressing out the water with a hydraulic press reduced the HCN content by 33% (Suismono and Wibowo, 1991). These steps are performed during cassava flour preparation (**Figure 1**), particularly for the bitter varieties. Nambisan and Sundaresan (1985) also reported that crushing the fresh roots and subsequent sun-drying was the most effective method, which may reduce the HCN content by >95%. This is due to the efficient hydrolysis of the cyanogenic glucosides as maximum contact between the enzyme and the substrate is obtained.

In the processing of cassava fresh roots into starch (**Figure 1**), the HCN released from bitter cultivars is seemingly dissolved into the water. Unfortunately, up to the present the mode of action of HCN in the water is not clearly understood. Water pollution due to liquid and solid waste from the starch extraction industry is not merely caused by the release of the waste into the water ways, which leads to the rapid increase of biological and chemical oxygen demand (BOD and COD), but it seems that the release of large amounts of HCN into the rivers is also a problem. Measurements of HCN in the liquid waste pond as well as in the rivers nearby the factories revealed a level of 0.025 ppm. As mentioned previously, 5 million tonnes of fresh cassava roots are processed for starch in Indonesia yearly, and bitter cultivars having >100 ppm HCN are generally preferred. The water required for starch extraction is about 40 billion liters, and the HCN liberation into free water is about 500 tonnes yearly. It is a serious problem which justifies further research. There is a possibility to use HCN as a phyto-chemical insecticides. Bellotti and Riis (1994) reported the effectiveness of the use of HCN to control insect pests in the crop. It may be useful to initiate applied research on integrated pest management oriented towards a more sustainable approach. However, if HCN can not be used as a phyto-chemical, in order to avoid the high levels of HCN in waste water and the pollution of rivers and ponds, research in crop genetic improvement to develop cassava varieties with low levels of HCN should be conducted urgently.

DEMAND FOR BIOFUEL

The price of fossil fuel has recently increased dramatically due to rapid increases in demand and the limitation of oil reserves. In attempts to provide renewable fuel that is more ecologically friendly, the use of ethanol to partially replace gasoline is considered appropriate. In the early eighties (1982) an ethanol plant using cassava was established in Lampung in order to anticipate the future limited availability of fossil fuel. During the Dutch colonial period ethanol was produced from molasses (sugarcane), and several ethanol plants were established in East Java. Considering the experience from some developed countries that up to 85% of gasoline can be replaced by ethanol, Indonesia has started to use a blend of 5% ethanol with 95% gasoline. Indeed the government has a target to use 10% ethanol to produce "gasohol" (blend of gasoline and ethanol). Unfortunately the capacities of the existing ethanol plants are still low. Although in several areas of Java small- to medium-scale ethanol plants have been established, the ethanol produced is hydrous alcohol with 95% ethanol, which is not suitable as fuel-ethanol; to be suitable the hydrous alcohol needs to be further dehydrated until the ethanol content is 99.5%. The most serious problem is in providing sufficient raw material from cassava as well as from molasses. This phenomenon is similar to that faced by China and Korea in their ethanol plants, which also have difficulties in supplying the raw material. For that reason, both countries are importing *gaplek* from Indonesia. This is affecting the price of fresh cassava which has increased significantly, as there is competition for raw material between the starch industry and ethanol plants, as well as the fresh market and for feedstuff.

Table 5. Chemical composition and conversion rates of cassava into ethanol

Cassava cultivars	Root dry matter content (%)	Total sugar content (% wet basis)	Starch content (% dry basis)	Conversion into ethanol (kg fresh roots/liter)[1)]
Adira-4	39.51	40.93	80.31	5.20
Malang-6	43.07	39.12	80.46	5.51
UJ-3	41.34	36.22	79.57	5.43
UJ-5	46.31	43.47	80.24	5.52

[1)] Ethanol content 96% (distillation efficiency assumed 95%)

***Source**: Ginting et al., 2006.*

Compared to the starch industry, the ethanol plants are more ecologically friendly, because there is no liberation of HCN to open water ways such as from some starch factories. The amount of water required for ethanol processing is less than for starch extraction processing, so the pollution consequence is smaller, especially if the solid waste is used for animal feed. Yudiarto (2007) has recommended small-scale ethanol processing at the household level using 50 kg cassava roots with a starch content of 28% to produce 7.5 l ethanol. The procedures is as follows:

1. 50 kg of cassava roots are peeled, washed and meshed and put into a drum, adding 40-50 l of water followed by boiling.
2. Add 1.5 ml α–amylase enzyme and keep the temperature at 90°C for 30 minutes.
3. Bring to boiling at 100°C for 30-60 minutes, and then cool down to a temperature of 55-60°C.

4. Add 0.9 ml gluco-amylase enzyme, and maintain the temperature at 55-60°C during three hours.
5. Cool down to <35°C, then add 1 g yeast, 65 g urea and 14 g NPK. Let the fermentation process continue for 72 hours in the closed drum, but allow the release of carbon dioxide. The success of the fermentation process can be detected from the aroma of fermented cassava as well as the bubbling of CO_2 gas released and the pH level >4.
6. Move the liquid containing 7-9% ethanol to the evaporator drum.
7. Heat the evaporator drum until vapor produced enters the still. Then, condense the vapor into liquid by running cooling water through the outside mantle of the still.
8. Keep the temperature at the upper part of the still 79°C until liquid ethanol comes out from the bottom. The temperature can be controlled by adjusting the heating source or the reflux water in the still.
9. The liquid containing 90-95% ethanol will flow out gradually from the still.
10. Remove the liquid waste from the drum through an outlet. Both the liquid and solid waste can be used as feed for animals (goats, cows etc).

In the past the starch industry tended to build ever larger factories that ultimately resulted in many problems, such as the sustainability of raw material supply as well as pollution of the environment from waste. Therefore, for ethanol production the industry is considering to operate at small- to medium-scale rather than at large-scale. Large scale factories will purify this to high-quality fuel-grade ethanol with 99.7% ethanol that small- and medium-scale factories cannot reach. So, there are many opportunities for rural communities to gain a better income. The potential of cassava to be converted to bio-fuel is in line with the Millennium Development Goals (MDGs), particularly goal one, that is to reduce poverty and to alleviate hunger.

Second generation ethanol production that will utilize the solid waste from starch factories seems an appropriate way to reduce the problem of raw material competition. Thus, the solid waste, consisting of fiber (lignin, cellulose and hemicelluloses) and starch will be broken down into glucose through a delignification process. Although at the laboratory level this second generation ethanol has been successfully produced, to implement its production at an economic scale needs much further research and development (Soerawidjaya, 2008).

In East Nusa Tenggara province there exist a traditional technology for producing ethanol using the liquid substance generated from sugar palm (*Arenga pinnata*). The liquid is then fermented and distilled to produce flame-able ethanol of 60-70% purity. This indigenous knowledge should be taken into consideration by investors with interests to use cassava or other raw materials for ethanol production. In some of those areas, aside from sugar palm and cassava, farmers also grow sorghum but with insufficient management. Planting cassava and sorghum without soil tillage, no fertilizer application and no weeding, results in very low productivity. Indeed those three crops – sugar palm, cassava and sorghum – can all be utilized as sources of food, feed and energy while conserving the environment and the traditional landscape of sugar palm trees in the tropics.

Cultivation Progress

Although in early cassava experiments fertilizers were used and recommended, during the Dutch colonial period there are no reports indicating that farmers were informed about fertilizer use for cassava. This is probably so because during that period chemical fertilizers were not readily available. Fortunately, organic fertilizers were available, both animal and green manures. The farmers' habit continued this traditional practice until the early sixties. As a result of the green revolution, in which fertilizer application was promoted to support the potential of the new high-yielding varieties of cereals (particularly rice), cassava farmers also started using chemical fertilizers, at least as a source of N (urea and/or ammonium sulfate) to obtain better crop growth and yield. Based on research results about fertilizer application for cassava it was recommended that for every 1 t of fresh roots farmers should apply 2.3 kg N, 0.5 kg P, 4.1 kg K and 0.6 kg Ca (Veltkamp and de Bruijn, 1996); however, in general farmers apply only N. The reason for this is that the application of N has a distinct and direct effect on the color of leaves, which become a darker green color accompanied by more rapid top growth. The effect of other nutrients is slower and farmers cannot wait until the harvest to know the real effect on root production. A Field School on integrated cassava crop and resource management held in several districts of East Java, showed that better and significant yield increases could be obtained by applying a compound fertilizer such as Ponska ($N-P_2O_5-K_2O-S = 15:15:15:10$).

Compared with most other food crops, cassava has a longer growth duration. For this reason, farmers in general do not plant cassava in monoculture, but tend to practice intercropping with other crops, like cereals, legumes, chili pepper etc. Intercropping of cassava is widely practiced by farmers, in South America, Asia as well as in Africa. It seems that intercropping cassava is a practice that was not developed by research institutes or universities, but was initiated from indigenous knowledge. Research institutes and universities then improved the existing cassava intercropping systems using more quantitative methodologies (Leihner, 1985). Up to three cycles of intercrops can be planted during one growth cycle of cassava, of around one year. The first intercrop, usually upland rice or maize, is planted together with cassava. After the first companion crop is harvested, a second crop is planted between cassava rows. A third crop can possibly be inserted, if rainfall is adequate and space between the rows of cassava is wide enough. Besides cassava row arrangement, the lower leaves of cassava could be removed to increase light interception for the intercrop (Widodo, 2005).

The cassava plant population under intercropping can be the same as under monocropping by adjusting the planting arrangement. Using more appropriate crop and resource management practices, the yield of cassava under intercropping was not significantly different from that under monocropping. For instance, adequate soil tillage and weeding after the harvest of the first intercrop is necessary. Fertilizer application under intercropping must be based on the nutrient requirements of each crop in order to prevent competition for nutrients between the crops. In upland areas of East Java the rainy season is only about six months and the cassava population is kept below 10,000 plants/ha, similar as in monoculture. Intercropping cassava with maize at a population of 80% of monoculture maize is often practiced. After the maize harvest, cassava is managed like any cassava monoculture crop.

Intercropping cassava is mainly practiced by farmers in Java and Lampung as well as in transmigration areas where Javanese have settled. On the other hand, where cassava is planted in large-scale plantations for fulfilling the raw material needs of starch factories, cassava is planted only in monoculture. Although intercropping is generally recognized as being economically more profitable and technically feasible, in large-scale cassava plantations farmers prefer to cultivate cassava in monoculture. The reason is that intercropping requires more labor and is considered more complicated, so cassava intercropping at large-scale is not always feasible.

Because of the need to supply the daily demand of raw material to the starch factories in the form of fresh roots, the factories promote the planting and harvesting of cassava year-round. For that reason, large cassava plantations are found mainly in the humid tropics with adequate rainfall for at least nine months. Unlike cassava in small farmers' fields, in large plantations soil tillage, i.e. plowing, harrowing and ridging is done by tractor. The sustainability of large-scale cassava plantations depends on the level and stability of crop and resource management. In Musi Banyuasin in South Sumatra which was started in 1980, a cassava plantation in an area of around 2500 ha could not be sustained due to many complicated factors. Heavy rainfall (>3000 mm/year) in an undulating area induced severe soil erosion, while a decreasing pH (4.2-4.8) and nutrient depletion were serious problems, which prevented the maintenance of high yield levels above 30 t/ha of fresh roots. Poor growth of cassava during the early stages of crop development, triggered excessive weed growth, especially *Axonopus sp.*, *Boreria sp.* and *Mikania sp.*, which competed with cassava for light and nutrients. After about 20 years the plantation was not able to supply the demand of the factory. Moreover, the market demand for starch is growing progressively. A similar decline in productivity in large-scale cassava plantations was also experienced in Lampung and in North Sumatra. For that reason, a partnership between the factory and farmers in the form of nucleus estate smallholders (NES) was developed, in the cassava starch industry.

Expansion of the Cassava Growing Area

In order to meet the increasing demand for cassava, in 2007 the government decided to expand the cassava harvested area by 850,000 ha, distributed in various districts throughout those provinces with conditions for the establishment of cassava. Unfortunately, of the target of 850,000 ha less than 10% or 57,000 ha could be achieved. The main problems relate to the shortage of planting material, and also poor infrastructure (access roads) for distributing the planting material and inputs. Unlike crops using sexual seed for multiplication, in cassava the multiplication rate is not as quick as in cereals and legumes. Therefore, the expansion of cassava into new areas requires more time, and it is more costly to establish plantations in large areas.

The raw material requirement of the large-scale cassava starch factories varies from 600 up to 2,000 t of fresh roots daily. This large amount is difficult to supply, except during the peak harvest period. Consequently, in the outer islands (outside of Java), the cassava starch factories are mainly supplied by large cassava plantations, where continuous planting is practiced to maintain the daily raw material supply. In Sumatra, Kalimantan and Sulawesi, cassava plantations have been established in previously forested areas. This fact is now strongly opposed by environmental groups. Since 1998 there has been an euphoria of freedom, called the "reformation", which had a detrimental effect on forests.

Many forested areas were occupied by people who converted it into agricultural land for growing food crops, especially cassava. In many forested areas of Java cassava was planted intercropped with upland rice, maize, or groundnut. The crop's low input requirement as well as its high adaptability to grow in marginal environments encouraged farmers to plant cassava. Although the price was low, it was still economically profitable according to poor farmers. To conserve the forest as an important global resource, it is not recommended to grow cassava in forest areas where the slope is >30%. Only by practicing alley cropping systems in sloping and undulating areas, soil erosion can be prevented or at least reduced to acceptable levels.

Aside from Java and Sumatra, arable land in Kalimantan, Sulawesi, Nusa Tenggara, Maluku and Papua have been visited by investors to determine the possibility of cassava development in order to meet the huge demand for the food, feed, starch and ethanol industries. Unfortunately, due to poor road access and lack of other infrastructure facilities as well as labor scarcity, most foreign and domestic (from Java and Lampung) investors hesitate to open new cassava areas in the eastern parts of Indonesia. In addition, there is a large effort under way to increase cassava production in Java and Lampung to meet the increase in domestic demand and from abroad, especially from China and Korea, which like to import *gaplek* for ethanol production. That was the main reason to revitalize the Mukibat system (**Table 6**). Starting about five years ago, the Mukibat system was resurrected and disseminated in many districts of Java and Lampung in order to meet the huge demand for cassava roots.

Table 6. Advantages and disadvantage of Mukibat and ordinary cassava (based on field observation 2007/08).

Items	Mukibat	Ordinary cassava
Multiplication rate	1:1*	1:10
Spacing (cmxcm)	200x150	100x100
Population	3,300	10,000
Cost (of each seedling in Rp)	1,000	125
Land preparation	Mound	Flat, ridge or mound
Intercropping	Only able to intercrop with one crop due to heavy shading from cassava plants	Arranged in double rows permit 2-3 associated crops
Replanting risk (%)	>30, broken due to wind, failure of grafting union, termites etc.	<8, due to poor cutting quality, time lag from harvest till planting, erratic rainfall etc
Organic fertilizer requirement (t/ha)	≥5 kg/plant (15-20 t/ha)	Applied if available
Cost of production (Rp/ha)	15,000,000	5,200,000
Yield level (t/ha)	>80	15-40
Cost/kg fresh root (Rp/kg)	187.5	130-347

*After harvest the Mukibat graft can be used again as planting material, this is called *randan* meaning 'widow'. This "widow" graft can be reused 1-4 times. The highest yield is obtained from the first widow planting (risk <5%); US$ 1.0 = Rp 9,230.

The large-scale implementation of the Mukibat system is being evaluated for its technical and economic feasibility by farmers. From experiments conducted by Brawijaya University from 1974 to 1984, it was concluded that the Mukibat system had many advantages; however, most cassava farmers think that it is very laborious. With insufficient nutrient application (organic manure especially), and planting in shallow soil, the yield of Mukibat cassava is comparable to that of ordinary cassava, but the risk is higher for the Mukibat system. Farmers in Banyuwangi, in one of the eastern districts of East Java, due to the high demand of cassava as a snack food in Bali, prefer the Mukibat system as the best way to sustain their supply. In these areas, a sweet and yellow-fleshed local variety is used as the rootstock and *Manihot glaziovii* as the scion. This system is widely used by farmers for more then 15 years without any support from the government or investors. In Pacitan, a southwest district of East Java, and Wonogiri, a southeastern district of Central Java, investors from China as well as domestic developers have promoted the use of Mukibat in large areas designated for ethanol production or for export as *gaplek* to an ethanol plant in Guangxi, China.

Using good quality cuttings from the new high-yielding cultivars is one of the best ways to achieve higher productivity. To earn additional cash income, farmers do not necessarily need to expand the harvested area. Proper soil tillage, the use of organic and inorganic fertilizers to prevent soil nutrient exhaustion by nutrient removal in the roots of the previous harvests is very important. Maintaining a cassava plant population at 10,000/ha, similar to that used in monoculture, but with a plant arrangement of 200 cm between rows and 50 cm between plants in the row provides space for twice planting of intercrops. This kind of intensive management can be practiced by farmers and prevents the forest area from being destroyed by illegal logging.

New High Yielding Varieties

Widodo (1995) suggested the need to develop high-yielding sweet, low HCN cassava cultivars in order to provide safer food for the people that use cassava as a staple food and simultaneously reduce the pollution by the release of toxic waste from cassava into the environment. About 463 cassava cultivars have been collected in Indonesia, which include local and newly released varieties as well as breeding lines (Antarlina and Harnowo, 1992). Since in Indonesia a high proportion of cassava is used for human consumption and a smaller part is used for industrial purposes, most farmers grow local, mainly sweet, varieties, which also have good taste and cooking quality characteristics, even though the potential yield is relatively low. In cassava producing areas, such as South Malang, about 48% of farmers grew local varieties, mostly sweet varieties, such as Randu, Putih, Tapak Lumut, Mantel, Sumatra, for direct consumption, 33% grew improved varieties, mostly bitter varieties, such as Sembung or Faroka for *gaplek* and starch preparation, and 19% of farmers planted both types of varieties (Ginting *et al.*, 1993). This shows a need for the availability of improved varieties with high yield potential, low cyanide content and good cooking quality.

A level of 100 mg HCN-equivalent per kg fresh roots has been used as an upper limit for low cyanide varieties in breeding programs since 1954 (Hahn, 1985, *in* Rosling, 1994). Regarding improved varieties that have been released in Indonesia from 1978 till 2002, some of these have high yield potential with low cyanide content (<50 mg/kg), such as Darul Hidayah, Malang 1 and Malang 2 (**Table 7**), while the rest have relatively high cyanide contents. Since 1997, studies on breeding and selection of cassava cultivars for high yield potential (>35 t/ha) as well as good taste and cooking quality and with an HCN content below the level found in Adira 1 (27.5 mg/kg) have been pursued at ILETRI. Currently, about ten cassava clones have been selected (Ginting *et al.*, 1999; Sundari *et al.*, 2000; Hartojo *et al.*, 2000) that meet above criteria, and these will be further developed and ultimately released after passing a series of stability and adaptability tests.

Table 7. Improved cassava cultivars released in Indonesia from 1978 to 2002.

Variety	Year of release	Yield potential (t/ha)	Starch content (%)	HCN content (mg/kg fresh roots)
Adira 1[1]	1978	22	29.50	27
Adira 2[1]	1978	22	25.00	124
Adira 4[1]	1987	35	27.25	68
Malang 1[1]	1992	36.5	26.30	<40
Malang 2[1]	1992	31.5	25.75	<40
Darul Hidayah[2]	1998	102.1	21.50	<40
UJ-3[2]	2000	25-38	26.00	>100
UJ-5[2]	2001	39.7	27.00	>100
Malang 4[3]	2001	36.4	26.50	>100
Malang 6[3]	2001	38.5	25.50	>100

***Source**: [1] Anonymous, 1993; [2] Anonymous, 2000; [3] Anonymous, 2002*

Different levels of cyanogenic glucosides are naturally present in cassava cultivars and different processing methods can have different effects on cyanide reduction. To guarantee food safety, it is highly recommended to be careful in the choice of cassava cultivars and to utilize effective processing methods for the preparation of a particular product. Cassava food products (mostly snacks) obtained through boiling, steaming or frying should be derived from cassava cultivars with HCN content <50 mg/kg as cyanogens can not be completely removed through such processing methods. This is particularly important for many traditional food processors who normally prepare snacks from cassava. They sometimes find it difficult to obtain sufficient raw materials of fresh cassava with low cyanide content due to seasonal availability in the markets. Using cultivars with relatively high cyanide content and processing these with normal processing methods could result in cassava toxicity, ranging from the milder forms to severe ones. Hence, awareness and knowledge on effective processing methods, such as soaking the peeled roots overnight and changing the soak water several times prior to cooking as well as discarding the boiling water, are very essential.

Conversely, cassava cultivars with relatively high cyanide content can be used for the preparation of *gaplek*, starch and flour as a combination of soaking, slicing/shredding, pressing and sun-drying is performed, which are known to be very effective in reducing the cyanide content, as discussed previously. The national standard requirement for *gaplek* flour and cassava flour was set at a maximum level of 50 mg and 40 mg HCN per kg fresh roots, respectively, while there is no maximum standard level for starch (Purwadaria, 1989;

SNI, 1991; SNI, 1992). Through processing steps shown in **Figure 1**, lower levels of HCN relative to the set maximum level can normally be achieved.

The starch industry is not so dependently on the quality of the fresh cassava roots used as raw material, especially as related to HCN content. But since the starch extraction process will liberate HCN from the fresh roots into the waste water, which may cause pollution of rivers and ponds, low-HCN varieties are recommended for use as raw material.

Minimizing Waste for a Better Environment

Following the green revolution approach, productivity and production increases are important goals, but many problems may be encountered at this stage, so called "first generation" problems. Subsequently, after these problems have surfaced efforts are made to minimize yield losses by improving processing, storage and distribution; these are called "second generation" problems. Unfortunately, attempts to alleviate the first and second generation problems resulted in detrimental effects of pollution of the environment. These "third generation" problems need to be tackled immediately, because the need for a clean and healthy environment is crucial, not only for the present but also for future generations. It means that in attempts to optimize the starch extraction processes by using large amounts of water, the third generation problems should be tackled using a holistic and integrative approach.

Several new high-yielding and high-starch cultivars have been developed, but due to the existing practice of optimizing the efficiency of starch extraction, this may have resulted in environmental problems. Widodo *et al*. (2002) reported that the age of plants at harvest is one of the determinant factors to achieve a high starch content and reduce wastes. When the price of cassava is high, due to lack of supply, a young crop of <8 months old is sometimes harvested to meet the high demand. In fact, this practice will increase the water requirement for starch extraction, and simultaneously produces more liquid as well as solid wastes. From research results we know that waste water could be reduced and re-used for further processing, but this is expensive and too sophisticated, so this is seldom practiced, either in small- or large-scale factories. Several large-scale starch factories were equipped with waste water treatment ponds, but these facilities are more like monumental showrooms, which are operated only during the visits of guests or policy makers, while in the daily operation waste water is directly released to the river or large ponds without any treatment. At the national level, the processing of 5 millions tonnes of cassava requires 40 millions m^3 of fresh water which will be converted into waste water. This amount of water could fill an irrigation channel of 40,000 km length and 1 m width to a depth of 1m.

It seems that in both small- and medium-scale starch factories the management of waste water would be easier. In Ngadiluwih as well as in Mojo Kediri, waste water from starch extraction is used for irrigating and fertilizing crops such as papaya, sugarcane, cassava, maize, peanut, and even rice. According to farmers the use of liquid waste from cassava starch extraction was able to reduce the use of inorganic fertilizer. This practice is especially useful during the dry season when there is a water shortage for irrigation. The large-scale starch factories could do the same by providing mobile tanks for distribution of waste water to dry areas.

Waste Utilization from the Starch Industry

The characteristic bad smell surrounding cassava starch factories is an indication of air pollution, whether from small-, medium- or large-scale factories. This smell is a problem particularly for people who are not familiar with the starch industry. Fortunately, the permanent residents in the area generally do not care about the smell. In Ponorogo, in an area near a large-scale starch factory, people living 1.5 km from the factory complained about the smell and water pollution. Street demonstrations were undertaken to stop the operation of the factory. On the other hand, farmers and cassava traders were not allowed to stop. The factory must continue, because cassava fresh roots need to be processed. To solve this conflict, Widodo and Hartojo (2000) proposed to compromise by processing the waste into useful by-products.

The bad smell is mainly due to the formation of butyric acid and other organic acids. In fact, citric acid can be produced by inducing the fermentation process of solid waste (pulp). Furthermore, after the solid waste is removed, the citric acid produced can be used as the substrate for single cell protein which is a nutritious feed. Widodo and Hartojo (2000) proposed that the solid waste, particularly the peel and neck of the roots could be inoculated with chicken or cattle manure, or with urea or ammonium sulfate to be processed into organic fertilizer (**Table 8**). Improving the existing cassava starch industry into being more ecologically responsible is an important objective. By integrating the cassava starch industry with animal husbandry as well as various other enterprises, it is possible to create more employment opportunities and generate more income (Widodo, 1986; 1996). To use waste and other biomass from cassava as second-generation feedstock for production of ethanol needs to be further studied, and ultimately the waste from ethanol production can be used for animal feed. Biogas is an inexpensive source of energy, generated by fermentation of animal manure, which can help the community. Ultimately, the animal manure, after its biogas liberation, can be utilized as a source of fertilizer to sustain the cassava production system.

Table 8. Effect of the application of various organic fertilizers produced from solid waste of cassava starch processing from a large-scale factory after five weeks of decomposition in Ponorogo in 2000 on soil fertility parameters.

Treatments	C org (%)	N (%)	C/N	pH	P (%)	K (%)
Check (no treatment)[1]	10.43	0.40	26.07	7.39	0.15	0.64
Added EM-4 100 cc/l water	8.63	0.45	19.18	7.12	0.09	0.48
Added Urea 5%	7.72	0.65	11.87	6.50	0.22	0.48
Added Ammonium Sulfate 5%	8.03	0.85	9.45	5.70	0.14	0.48
Added cattle manure 50%	8.95	0.70	12.78	6.85	0.12	1.06
Added chicken manure 50%	8.24	0.65	12.67	6.70	0.26	6.27

[1] Before the treatment: C organic =15.74%; N = 0.28%; pH = 7.4; each treatment box contained 10 kg waste + additives; EM-4 = Effective Micro-organism as a source of liquid bio-fertilizer

SUMMARY AND CONCLUSIONS

Based on the historical facts of cassava development in Indonesia after about four centuries of cultivation and utilization, several conclusions can be drawn:

1. In the beginning the objective of cassava cultivation was to earn foreign exchange by exporting cassava to Europe for production of animal feed. Fresh roots, which are characterized by being a voluminous and perishable product, requires immediate conversion to a dried form (such as *gaplek*) to avoid its rapid deterioration; this is also a simple way to prepare the material for export.
2. Utilization of cassava from fresh roots or dried *gaplek* and starch, triggered by food scarcity conditions, promoted the spontaneous development of various local food products. The increase in domestic demand, mostly for direct consumption and food-related industries, was able to absorb the increased supply and even required the importation of some products to supplement the supply.
3. Cassava starch processing is one way to convert cassava fresh roots into a value-added intermediate product, which can be further processed into various final products. The starch industry requires a lot of water and often releases HCN into waste water, and ultimately into rivers. The existing traditional technology is not ecologically friendly, and results in complaints from the local community around the processing plant.
4. Bio-ethanol can be produced from fresh or dry cassava. The current level of production of fresh cassava has been completely allocated for specific usages, and any increase of cassava production can be directed to supplying the raw material of small- to medium-size ethanol plants by also incorporating other raw materials, such as from sugar palm, sorghum etc..
5. Second generation ethanol production can use the waste of starch factories, but this will need to be integrated with animal husbandry to reduce raw material competition and to create a better and healthier environment without major pollution.

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