

CYANIDE REDUCTION IN CASSAVA ROOT PRODUCTS THROUGH PROCESSING AND SELECTION OF CULTIVARS IN RELATION TO FOOD SAFETY

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ABSTRACT

Cyanide reduction in cassava root products through processing and selection of cultivars in relation to food safety. About 47% of cassava production in Indonesia was used for human consumption, both as a staple food and snacks. In terms of food safety, the natural presence of cyanogenic glucosides in cassava roots is of concern as they may release free cyanide (HCN), which is highly toxic. At high levels, it may cause acute poisoning, leading to death as well as iodine deficiency and neurological disorders for long-term ingestion. The cyanogenic glucosides content in different cultivars of cassava varied from 1 up to >1,000 mg HCN/kg fresh weight, while 10 mg HCN/kg dry weight was considered to be the safe level for consumption. Various processing methods were reported to be effective in reducing the cyanide content in cassava products. A decrease of 25–50% was observed during overnight soaking, while it was much higher (81%) when subsequent drying and milling into flour was performed. During boiling, steaming, deep-frying, baking and fermentation, a reduction of 45–50%, 17%, 13%, 14% and 38–84% was noted, respectively. Crushing the fresh roots and subsequent sun-drying was the most effective method with >95% of HCN removal. It suggests that low cyanide content of cassava cultivars (mostly sweet/local varieties) are obviously required for direct consumption purposes. This is particularly important for traditional food processors to be selective in obtaining fresh cassava as raw material and choosing proper processing methods. While for *gaplek*, starch, flour, and mocaf purposes, where washing, soaking, shredding, fermentation, pressing, drying and milling were involved, the bitter cultivars (mostly improved varieties) with relatively high cyanide content can be used. Therefore, breeding selection for cassava cultivars with low cyanide content and high potential yield is essentially needed. Selected improved varieties and promising clones seem to meet this criteria. Regulation for food in-

dustries to provide information on cyanide level in cassava food labels would also protect the consumers and promote safe cassava foods.

Keywords: cyanide, cassava, cultivars, processing, food safety.

ABSTRAK

Penurunan sianida pada beberapa produk ubikayu melalui pengolahan dan seleksi kultivar dalam mewujudkan keamanan pangan. Upaya penurunan kadar HCN pada ubikayu melalui pengolahan dan pemilihan varietas dalam kaitannya dengan keamanan pangan. Sekitar 47% produksi ubikayu di Indonesia dimanfaatkan untuk bahan pangan, baik sebagai makanan pokok maupun selingan. Dalam kaitannya dengan keamanan pangan, keberadaan alami senyawa sianogen glukosida pada ubikayu segar penting diperhatikan karena dapat menghasilkan asam sianida (HCN) yang sangat beracun. Pada konsentrasi tinggi, HCN dapat menyebabkan keracunan akut yang berujung kepada kematian. Di samping itu, konsumsi dalam jangka panjang juga dapat berasosiasi dengan terjadinya defisiensi iodin dan gangguan pada syaraf. Kandungan sianogen glukosida pada beragam jenis ubikayu berkisar dari 1 mg hingga >1.000 mg HCN/kg umbi segar, sementara batas aman untuk konsumsi ditetapkan sebesar 10 mg HCN/kg bobot kering. Beberapa cara pengolahan dilaporkan efektif untuk menurunkan kadar HCN pada produk olahan ubikayu. Penurunan kadar HCN sebesar 25–50% diamati pada perendaman satu malam, dan meningkat menjadi 81% bila dilanjutkan dengan pengeringan dan penggilingan seperti pada pembuatan tepung. Pada perebusan, pengukusan, penggorengan, pemanggangan, dan fermentasi, besarnya penurunan HCN masing-masing sebesar 45–50%, 17%, 13%, 14% dan 38–84%. Pemasakan umbi segar yang dilanjutkan dengan pengeringan sinar matahari merupakan cara yang paling efektif dengan tingkat eliminasi HCN >95%. Hal ini menunjukkan, bahwa ubikayu dengan kadar HCN rendah (jenis manis/tidak pahit yang umumnya varietas lokal) diperlukan untuk bahan baku olahan segar. Hal ini penting diperhatikan oleh industri makanan dalam memilih bahan baku dan cara pengolahan yang tepat. Sementara untuk *gaplek*, pati, tepung, dan mocaf, yang melibatkan proses pencucian, perendaman, penyawutan, fermentasi, pengepresan, pengeringan, dan penggilingan dalam pengolahan-

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nya, jenis ubikayu pahit (mayoritas varietas unggul) dengan kadar HCN relatif tinggi dapat digunakan sebagai bahan baku. Oleh karena itu, perakitan varietas unggul dengan potensi hasil tinggi dan kadar HCN rendah sangat diperlukan. Beberapa varietas dan calon varietas unggul tampaknya telah memenuhi kriteria tersebut. Selain itu, peraturan yang mewajibkan industri makanan untuk mencantumkan informasi kadar HCN pada labelemasannya juga akan melindungi konsumen dan mempromosikan keamanan produk olahan ubikayu.

Kata kunci: KCN, ubikayu, varietas, pengolahan, keamanan pangan

INTRODUCTION

Cassava is the third important food crop in Indonesia after rice and maize. The harvested area of cassava was about 1.18 million hectares with total production of 23.9 million tons (BPS 2010). About 47% of cassava was used for food, while the rest of 2%, 3%, 47% was available for feed, export and industry, respectively (FAOSTAT 2009). The apparent consumption

level of cassava was about 44.6 kg/capita/year (FAOSTAT 2009). This level was higher in rural areas relative to urban areas (Setyono *et al.* 1992). According to BPS (1999), about 6% and 21% of households in rural areas consumed tubers (predominantly cassava) every day and 2–5 times per week, respectively, while it was only 2% and 16%, respectively for those who live in urban areas.

Cassava is consumed either as a staple food or snacks. *Tiwul* is the most popular staple food derived from cassava, particularly in Java. It is made from flour of dried-sliced cassava (*gaplek*), which can be consumed directly after cooked, or dried as a storable instant *tiwul* (Ginting *et al.* 1989a). Whereas as snacks, fresh roots of cassava 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*. Not less than 90 different kinds of traditional foods can be prepared from fresh cassava (Setyono *et al.* 1992). These traditional foods are popular both in rural and

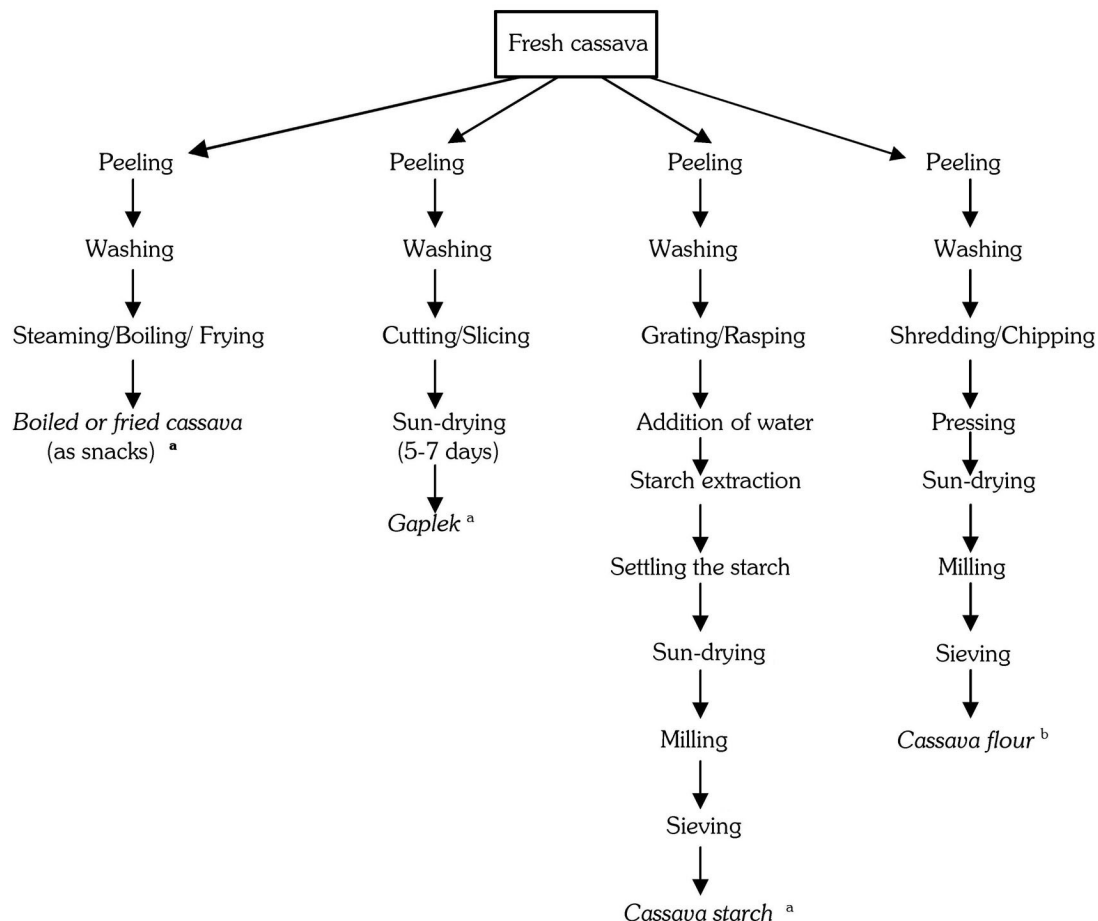


Fig. 1. Flow charts for the preparation of cassava snacks, *gaplek*, starch and flour.

Source: ^a Barret and Damardjati (1984); ^b Damardjati *et al.* (1996).

urban areas, however more types of snacks are found in rural areas.

Cassava can be also processed into intermediate products, such as *gaplek* (dried cassava roots), starch and flour (Fig. 1). *Gaplek* is normally prepared by farmers both for consumption (*tiwul*) and sale purposes. *Gaplek* can be further exported or used as an ingredient in feed industries. Whereas, starch is mainly produced for commercial purposes, both for food (*kerupuk* or cracker, sweeteners, thickener, filler, binder or stabilizer, organic acid) and non-food industries (chemical, textile, pharmaceutical) (Suyamto and Wargiono 2009). Cassava flour is compatible to be used in foods preparation, which need flour as a main ingredient. Various foods, including snacks, bakery products (cookies, cakes, breads) and noodles can be prepared from cassava flour blended with other flours, particularly wheat flour. The proportion of cassava flour varies from 10–100%, depending upon the kinds of products (Widowati and Hartojo 2001; Ginting *et al.* 2011).

In terms of food safety, the natural presence of cyanogenic glucosides in cassava roots is of concern due to their toxicities. The amounts of hydrogen cyanide (HCN), a representative toxic compound of cyanogenic glucosides in different cultivars of cassava varied from 1 up to > 1,000 mg/kg (Bradbury 1990). Cassava roots containing <50 mg HCN/kg was grouped as sweet cultivars, while the bitter cultivars had >50 mg HCN/kg. Cassava roots with >100 mg HCN/kg are not safe for consumption as it may cause acute poisoning and death (Coursey 1973 *in* Richana dan Suarni 1990). Therefore, the sweet cultivars are mostly chosen for fresh utilization of cassava roots. However, the bitter cultivars with relatively high HCN content tended to have high potential yield as well as starch content (Setyono *et al.* 1992; Ginting *et al.* 1999; Balitkabi 2011). These parameters are desired by breeders, starch and flour processors as well as farmers. On the other side, various processing methods of cassava roots showed different levels of cyanide reduction (Coursey 1973 *in* Bradbury 1990). Hence, the use of cassava roots for foods should combine effective processing methods in reducing HCN content with selection of cultivars with high potential yield and low cyanide content. This paper will discuss related subjects based on the results of Indonesian and overseas studies.

OCCURRENCE OF CYNIDE IN CASSAVA AND ITS RELATED TOXICITY

There are two cyanogenic glucosides present in cassava roots, namely linamarin that accounts for 95% of total cyanogen content and lotaustralin (Balagopalan *et al.* 1988 *in* White *et al.* 1994). These cyanogens are distributed widely throughout the plants with large amounts in the leaves and root cortex (Bradbury and Halloway 1988 *in* Cardoso *et al.* 2005). The hydrolysis of linamarin by the α -glucosidase and linamarase (with optimum pH of 5–6), resulted in the production of acetone cyanohydrin. It can be further decomposed to free cyanide (HCN) and acetone 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 soluble in water (Oke 1994). Liberation of free cyanide only occurs in physically damaged tissues due to crushing or maceration during processing, indicating that the enzymes and the substrate are located in different compartments in the cell (White *et al.* 1994). Linamarin is stored inside the cell, while linamarase is located in the cell walls (Mkpong *et al.* 1990 *in* Cardoso *et al.* 2005). Information on conditions required for such chemical and biochemical changes are important in controlling HCN reduction during processing.

The lethal dose of cyanide for humans was reported to be 0.5–3.5 mg HCN/kg body weight, which was about 30–210 mg HCN for a 60 kg adult (Montgomery 1980 *in* Okafor 2004). The human body is able to detoxify as high as 100 mg of HCN for 24 h by rapid conversion of cyanide to the much less toxic thiocyanate, which is then excreted in the urine. Tyllekar *et al.* (1992 *in* Okafor 2004) also reported there was no evidence of acute effect of cyanide exposure rates below 100 mg HCN per 24 h. However, high levels of cyanide ingestion may cause acute cyanide intoxication, which particularly may occur in cassava eating population due to consuming insufficient removal of HCN during cooking. The predominant symptoms include nausea, vomiting, dizziness, stomach pains, headache, diarrhea, weakness and sometimes collapse that occasionally leads to death (Rosling 1994). In addition, the conversion of cyanide to

thiocyanate uses the sulphur containing amino acid (cystein and methionine), hence consumption of low protein foods (common situation in cassava eating population) would enhance the toxic effects (Rosling 1994).

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). Hence, these consequences are not solely caused by overload thiocyanate in human body due to long ingestion of cyanide, but 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 neuropathy that usually occurs among adult males and results in an uncoordinated gait, called ataxic, loss of vision, deafness and weakness (Osuntokun 1994 *in* Cardoso *et al.* 2005). The next is epidemic spastic paraparesis, a spastic paralysis of both legs (*Konzo*) that mainly affects children and women of child bearing age, particularly noted in eastern, central and southern part of Africa (Howlett 1994 *in* Cardoso *et al.* 2005). All above facts show that cassava related diseases and consequences are considerably related to food insecurity, agro-ecological crisis and severe social economic circumstances.

REDUCTION OF CYANIDE CONTENT IN CASSAVA ROOT PRODUCTS THROUGH VARIOUS PROCESSING METHODS

Various processing methods showed different levels of cyanide reduction in cassava root products. Activities like crushing or physically damage the root tissues, using large amounts of water and dehydration, which are normally

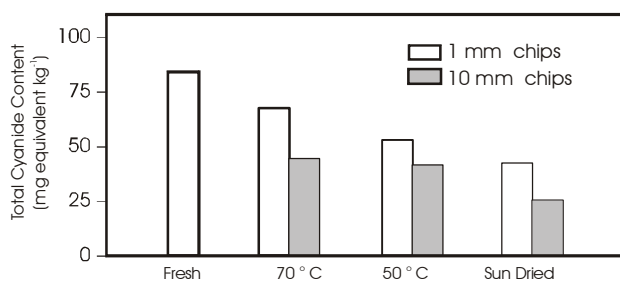


Fig. 2. Removal of cyanogens from cassava

Source: Nambisan and Sundaresan (1985).

involved during processing, allow to enzymatically break down the cyanogenic glucosides to cyanohydrins and followed by degradation of cyanohydrins to HCN. HCN will easily disappear due to its volatility and dissolvability in water.

According to Richana and Suarni (1990), soaking (20 h) of peeled cassava roots in water (1:3 w/v) reduced about 37% of HCN content. The reduction level was higher (50%) in the bitter varieties of cassava relative to the sweet varieties (25%). Subsequent drying the soaked roots to obtain *gaplek*, followed by milling it into flour resulted in much higher cyanide reduction (70%) and up to 81% for the bitter varieties. The HCN content found in *gaplek* and cassava flour was below 50 mg/kg, suggesting that soaking and drying are efficient in reducing HCN content. Nebiyu and Getachew (2011) also reported that soaking cassava chips in water for 24 h prior to sun-drying, substantially gave 74–90% HCN reduction. In addition, shredding of peeled cassava roots and subsequently pressed using a hydraulic press could reduce 33% of the HCN content (Suismono and Wibowo 1991). This step is necessarily performed during cassava flour preparation (Fig. 1), particularly for the bitter varieties. Nambisan and Sundaresan (1985) also revealed that crushing the fresh roots and subsequent sun-drying was the most effective method, which may reduce HCN content up to > 95%. This is due to efficient hydrolysis of the cyanogenic glucosides as maximum contact between the enzyme and substrate occurred.

In drying process, levels of cyanide removal are considerably dictated by the thickness of chips and drying temperature (Nambisan and Sundaresan 1985). High temperature (70 °C) showed less reduction in total cyanogenic glucosides relative to low temperature (50 °C and sun-drying) (Fig. 2). Using oven drying at higher temperature (100 °C), Tivana *et al.* (2007) obtained much lower cyanide removal in cassava chips (9–23%). Similar finding was also observed in thin chips, giving a lower reduction of total cyanogenic glucosides than that of thick chips. This is due to faster drying at high temperature and in thin chips, thereby depleting moisture, which is essentially needed for the enzyme action. Sun-dried chips showed the highest levels of total cyanogenic glucosides removal, which was 67–73% for 3 mm chips and 42–48% for 10 mm chips (Fig. 2). The fastest loss of cyanogenic glucosides (75%) occurred particularly during the first three hours of sun-drying (Fig. 3),

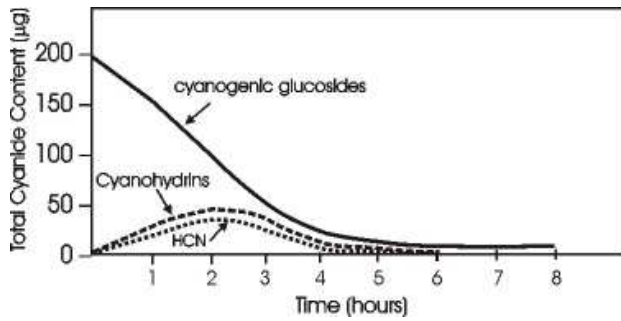


Fig. 3. Mode of cyanogens during crushing chips during drying, and sun-drying process.

Source: Nambisan and Sundaresan (1985).

followed by the increase amounts of HCN and cyanohydrins. Minimal amounts of the three cyanogens were found after six hours of drying.

The extent elimination of cyanogens during cooking depends on the boiling time, volume of water used and the root piece sizes (Padmaja 1995 in Ravi and Padmaja 1997). Losses of 45–50% of HCN content have been observed in cooked cassava roots for 30 min (Nambisan and Sundaresan 1985). Richana and Suarni (1990) also found HCN loss of approximately 25% and 50%, respectively for the sweet and bitter varieties during boiling. It seemed that the smaller the size of cassava roots, the higher removal of HCN was obtained. Cooke (1983 in Cardoso *et al.* 2005) noted about 55% linamarin loss during boiling of cassava chips for 25 min. Similarly, the use of larger volume of water up to 1 : 5 (w/v), the higher level of HCN reduction was noted (76%) relative to 1:1 (w/v) that was only 30%. This suggested that sufficient amount of water was needed for solubilising maximum amount of HCN in boil-

ing process. Other methods of cooking, like steaming, deep-frying and baking showed substantial lower cyanide reduction in comparison to boiling, which was about 17%, 13% and 14%, respectively as shown in Table 1.

Furthermore, fermentation was also effective in reducing HCN content in cassava roots. During *fofofo* preparation, which is widely consumed in western Africa, fermentation was done by soaking the peeled roots in water at 30 °C for 48 h, resulting in 84% removal of total cyanogens (Blanshard *et al.* 1994). Softening the cassava roots as a result of microorganism activities, accompanied by increased hydrolysis of cyanogenic glucosides by the endogenous linamarase and the microbial α -glucosidases as well as the ability of the microorganisms to use free cyanide seem to be the main causes for cyanogens reduction during fermentation (Bokanga *et al.* 1990). However, a drop of pH to about 4, particularly in fermentation which organic acids are the intermediate or final products, may alter the activity of linamarase as its optimum pH is around 5–6. *Gari*, another African fermented product that was prepared through grating the roots, bagging, soaking/fermentation for 2–5 days, drying and roasting, remarkably showed HCN removal (91–99%) (Adaku and Dkafor 2010). HCN reduction at levels of 38–61% were observed in *tape*, an Indonesian fermented cassava that collected from different processors. The *tape* samples were derived from local varieties of cassava with HCN content of 69–77 mg/kg (Ginting *et al.* 1989b), reflecting that preparation methods highly influenced the final HCN content in fermented cassava products.

Fermented or modified cassava flour (mocaf) is currently popular in Indonesia due to its better

Table 1. Effect of different processing methods on cyanogens removal in cassava.

Process	Cyanogen content (mg HCN equivalent/kg)		
	Variety H-165	Variety H-2304	Variety H-1687
Fresh cassava	140.0 ± 4.2	82.5 ± 1.3	58.2 ± 1.2
Boiling	77.6 ± 1.6 (44.5)	43.5 ± 0.8 (47.3)	30.7 ± 0.5 (47.4)
Baking	122.0 ± 2.8 (12.9)	70.1 ± 1.3 (15.0)	49.6 ± 1.1 (14.8)
Frying	125.0 ± 2.5 (10.7)	75.2 ± 1.3 (8.8)	49.8 ± 1.4 (14.7)
Steaming	121.0 ± 2.5 (13.5)	70.0 ± 1.5 (15.2)	47.5 ± 1.6 (18.4)
Drying	99.2 ± 1.8 (29.2)	60.5 ± 1.4 (27.8)	43.5 ± 0.9 (25.0)

Source: Nambisan and Sundaresan (1985). Percentage of removal is given in parentheses.

properties compared to native cassava flour. These include the whiteness level, aroma, rehydration/water solubility and baking expansion capacity (higher peak viscosity). Therefore, higher proportion of mocaf can be applied as a wheat flour substitute (up to 100%) in the preparation of bakery products, cookies, cakes, noodles and traditional snacks (Misgiyarta *et al.* 2009; Yulifianti *et al.* 2012). Fermentation in mocaf processing is done through bagging the shredded/chipped roots, then soaking in water inoculated with microflora/starter (particularly *Lactobacillus* spp) for 12 h (Misgiyarta *et al.* 2009) prior to pressing and drying. Yulifianti and Ginting (2012) obtained slightly lower HCN levels in mocaf (8.6–16.7 mg/kg) relative to those of unfermented flour (13.7–22.0 mg/kg) derived from five cassava cultivars. Much lower HCN content in fermented cassava flour (17 mg/kg) than that of unfermented cassava flour (158 mg/kg) was reported by Tivana *et al.* (2007) who applied moulds and bacteria as starters for fermentation (4–5 days). Longer fermentation seems to give higher cyanide reduction due to leaching out into the soak water as well as hydrolysis of linamarin by the microflora produced linamarase. Kobawila *et al.* (2005) noted that considerable cyanide reduction occurred after 48 h fermentation of cassava roots (70.67%) compared to 24 h fermentation (6.86%).

Wetting is another simple method that could reduce cyanide content in cassava flour (Bradbury 2006). Cassava flour is thoroughly mixed with water in the ratio of 1:1,25, then leaves for 5 h at room temperature (30°C) prior to cooking. Using this method, about one third of cyanide can be reduced due to the activity of linamarase that is expectedly present in the flour treated with drying temperature below 70 °C (enzyme/protein denaturation). The addition of water facilitates the optimum pH (around 6) for linamarase activity and hydration for hydrolysis process. However, this method was not effective for cassava flour samples obtained from Indonesia due to insufficient amounts of linamarase in the samples (Bradbury 2006).

SELECTION OF CASSAVA CULTIVARS FOR LOW CYANIDE CONTENT

About 250 cassava cultivars have been collected in the ILETRI germplasm, which included local, introduction and improved varieties as well as crossed cultivars (Kasno 2011). Local varieties (mainly sweet varieties) are mostly grown

for direct consumption as they 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 sweet varieties, such as Randu, Putih, Tapak Lumut, Mantel, and Sumatra for direct consumption purposes, 33% local bitter varieties, such as Sembung and Faroka for *gaplek* and starch preparation and 19% farmers planted both varieties (Ginting *et al.* 1993). Meanwhile in Lampung, where cassava is used mainly for industrial purposes, bitter improved varieties with high yield and starch content, such as UJ 3 and UJ 5 are mostly grown. However, along with industrial development of fresh cassava-based foods in the market, particularly deep-fried crisps/chips, the availability of improved varieties with low cyanide content, high potential yield, and good cooking quality is essentially needed.

A level of 100 mg HCN equivalent per kg wet weight or per kg fresh roots has been used as an upper limit for low cyanide breeding program since 1954 (Hahn 1985 *in* Rosling 1994). Regarding improved varieties that have been released in Indonesia since 1918 until 2011, only five varieties have low cyanide content (<50 mg/kg), namely Adira 1, Malang 1, Malang 2, Darul Hidayah, and Litbang UK 2 while the rest showed relatively high cyanide content (Table 2). Since 1997, studies on breeding selection of cassava cultivars for high potential yield (>35 t/ha) as well as good taste and cooking quality with HCN content below the level found in Adira 4 variety (68 mg/kg) have been performed at ILETRI. About 10 cassava clones have been selected (Ginting *et al.* 1999, Sundari *et al.* 2000; Hartojo *et al.* 2000), which met above criteria and will be further developed and ultimately released after passing series of stability and adaptability tests. Three promising clones, namely CMM 99088-3, CMM 02048-6 and OMM 9076 are potential to be released as improved varieties with low cyanide content and good cooking quality (Table 2). Selected local varieties belonging to sweet cultivars, namely Manggu, Ketan, and Local Nganjuk are also suitable for ready to eat food ingredient, particularly deep-fried chips.

In addition to conventional breeding, effort to generate cyanogens-free transgenic cassava was also performed through inhibition the expression of the cytochrome P450 genes (CyP 70D1 and CyP 70D2) which catalyze the first-dedicated step in linamarin synthesis (Sirtunga

Table 2. Improved varieties of cassava released in Indonesia and selected promising clones

Variety	Yield (t/ha)	Starch (% ww)	HCN (mg/kg ww)	Year of released
Adira 1 ^a	22	45 *	27.5	1978
Adira 2 ^a	22	41 *	124	1978
Adira 4 ^a	35	18–22	68	1987
Malang 1 ^a	36.5	32–36	<40	1992
Malang 2 ^a	31.5	32–36	<40	1992
Darul Hidayah ^a	102.1	25–31.5	<40	1998
UJ 3 ^a	20–35	20– 7	>100	2000
UJ-5 ^a	25–38	19–30	>100	2000
Malang 4 ^a	39.7	25–32	>100	2001
Malang 6 ^a	36.4	25–32	>100	2001
Litbang UK 2 (OMM 9908-4) ^c	42.2	31.2	31	2012
CMM 99088-3 ^b	32.2 ^c	31.3	12.5	–
CMM 02048-6 ^b	35	31.2	27.9	–
OMM 9076 ^b	40	30.5	17.9	–

Source: * Dry matter content; ^a Balitkabi (2011); ^b Sholihin *et al.* (2009); ^c Sholihin *et al.* (2011).

and Sayre 2003). Using a leaf specific promoter to drive the antisense expression of CyP 70D1/CyP 70D2 genes, a reduction in linamarin content up to 94% was observed in the leaf associated with an inhibition of CyP 70D1/CyP 70D2 expression. The linamarin content of the roots was also reduced by 99% in transgenic plants having between 60–94% reduction in leaf linamarin content. This reflects that linamarin is transported from leaves to roots, which needs a threshold level of linamarin production in the leaves for transport. Hidayat *et al.* (2002) also reported a positive correlation ($r = 0.53$) between cyanogens in the leaves and in the roots derived from 45 Indonesian cassava cultivars.

RELEVANCE OF SAFE LEVEL CONSUMPTION OF CASSAVA

The safe level for consumption of cassava products/flour has been established as low as 10 mg HCN equivalent per kg dry weight by the Codex Alimentarius of FAO/WHO (1991). This level would allow consumers to have an intake of 5 mg per 24 h. However, Rosling (1988 *in* Lynam 1994) estimated that ingestion of 5–100 mg HCN per 24 h was still safe even at low levels of protein intake and ingestion of >100 mg can be detoxified under normal dietary intake in adult subjects. The upper limit for cassava breeding was also set at a level of 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 is likely too low, hence needed a higher level as cut-off point. Using such safe level, only 14% of cassava flour samples in Nampala, Mozambique had HCN content of <10 mg/kg (Cardoso *et al.* 2005). Estimation of the safe level should be based on cyanide detoxification rates in humans, necessary safety margins for natural toxins, degree of cyanide release from ingested cyanogens, expected daily consumption and degree of cyanogens removal during processing (Okafor 2004).

Indonesia therefore has established a higher safe level for national quality standard of cassava flour (40 mg HCN/kg) (DSN 1996). However, Djazuli and Bradbury (1999) observed that the mean total cyanide content of cassava flour obtained from Indonesia was 54 mg/kg and ranged from 22 mg to 74 mg/kg for samples taken in Bogor according to Yeoh and Egan (1997). In terms of cassava food products, Miles *et al.* (2011) noted that about 374 samples of cassava-based snack foods collected from New South Wales, Australia contained 13–165 mg HCN equivalent/kg. Lower levels of HCN were seen in a number of cassava food products originated from Indonesia (Table 3). These figures highlighted a wide range of HCN content in

Table 3. HCN content of selected food products prepared from cassava

Food products	Ingredient and preparation method	HCN content (mg/kg)
Tapioca crackers	flour	15 ± 7
Tapioca crisps	flour	41 ± 15
Tapioca chips	flour (seaweed)	53 ± 12
Opak sambal	flour	21 ± 5
Ubi rebus	steamed whole roots	19.3 ± 1.9
Getuk ubi	steamed grated roots	14.6 ± 1.2
Ongol ubi	steamed grated roots	8.2 ± 0.6
Talam ubi	steamed grated roots	4.1 ± 1.2
Kue bingka	baked grated roots	2.2 ± 0.7

Source: Anonymous (2005).

cassava flour and food products, some of which were above the safe level.

In addition, the safe level 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 be also absorbed and excreted unchanged in the urine. While cyanohydrins yield cyanide rapidly in the alkaline environment found in the small intestine (Cook *et al.* 1982 in Banea *et al.* 1995). These cyanogens might have toxic as well, hence establishment of the safe levels for these cyanogens consumption seems to be warranted.

Concerning different levels of cyanogenic glucosides naturally present in cassava cultivars and different effects of processing on cyanide reduction, with respect to food safety, it is highly recommended to be selective in choosing cassava cultivars and effective processing methods for preparation of a particular product. Cassava food products (mostly snacks) prepared through boiling, steaming, baking or deep-frying process obviously should be derived from cassava cultivars with HCN content <50 mg/kg as cyanogens cannot be completely removed through such processing methods. This is par-

ticularly important for traditional food processors who normally prepare snacks from fresh cassava. They sometimes have difficulty in obtaining sufficient supply of cassava with low cyanide content due to seasonal availability in the fields/markets. Using relatively high cyanide content of fresh cassava treated with normal processing methods would result in consequences of cassava toxicity 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 boil water are essentially needed. Furthermore, rainfall conditions during growth period of cassava plants in a particular area also need to be concerned as total cyanide levels in the roots increased in a year with low rainfall (drought) due to water stress on the plants (Bokanga *et al.* 1994 in Cardoso *et al.* 2005).

Conversely, cassava cultivars with relatively high cyanide content can be used for the preparation of *gaplek*, starch, flour, and mocaf as washing, soaking, slicing/shredding, fermentation, pressing and sun-drying process are involved, which are known to be very effective in reducing cyanide content as discussed previously. Through processing steps as given in Fig.1, lower levels of HCN relative to the set maximum level can be normally achieved.

In order to protect the consumers, the agency of national food control might need to establish regulation for food industries to provide information on cyanide content of cassava food products in their nutrition facts label. Consequently,

the food industries have to be aware of the nature and variation of cyanogens content in their raw material (cassava roots), perform proper processing methods that would give maximal removal of cyanogens, monitor residual cyanogens in the food products and use standardized analytical methods to suit the regulation as well as to promote safe cassava foods for consumers (Anonymous 2005).

CONCLUSIONS

The presence of toxic cyanide in cassava is of concern in relation to food safety as cassava is considerably used for human consumption in Indonesia. Exposure to cyanide at high levels may result in acute poisoning, leading to death as well as iodine deficiency and neurological disorders for long-term ingestion. The safe level for consumption of cassava products has been set at a level of 10 mg HCN equivalent per kg dry weight. Re-estimation of this safe level is needed as ingestion up to 100 mg per kg per 24 h likely can be detoxified in humans. Establishment of safe levels for individual cyanogens is also warranted.

Processing methods, such as soaking, boiling, steaming, deep-frying and baking would reduce cyanide <50%, while fermentation gave a higher value (up to 84%). The most effective method was crushing the fresh roots and followed by sun-drying, which may remove >95% of cyanide content. High variation of cyanide content in cassava roots leads to selectively choose cassava cultivars as well as effective processing methods for the preparation of different food products. For direct consumption, particularly as snacks, sweet cassava cultivars with <50 mg HCN/kg is highly recommended, while bitter cultivars can be used for *gaplek*, starch and flour preparation. Breeding selection for high potential yield as well as low cyanide content is essentially needed with respect to increasing cassava production as well as the safety use of cassava for foods. Selected improved varieties and promising clones seem to meet this criteria. Elimination of cyanogens in cassava roots is also possible through generation of cyanogens-free transgenic cassava. Regulation through providing information on cyanide level in cassava food labels would protect the consumers and promote safe cassava foods.

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