e-ISSN : 2621-9468

Type of the Paper (Article)

Revisiting how the Javanese traditional food safety practice significantly reduces cyanide concentration of marketed cassava roots

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Abstract

Despite being one of the most popular staple foods in Indonesia, cassava roots contain cyanide that can cause death without proper processing. In traditional market, however, the variant of the roots, hence their exact cyanide concentration, is mostly unknown. Despite that, Javanese have successfully been curbing the cassava poisoning risk through generations. To revisit the role of the local food safety practice in reducing the cyanide concentration, this study investigated and simulated how Javanese in Malang Regency, East Java, Indonesia, traditionally prepare cassava roots for consumption. Two commonly marketed roots; white and yellow; were selected and cooked by steaming or roasting. The cyanide concentration of each stage was measured by picric acid method optimized for cassava roots. The analyses demonstrated that 30 min steaming peeled roots, as well as 50 min steaming and 30 min roasting the unpeeled roots reduced the cyanide content to 12-18 ppm, below the Indonesian acceptable limit of 40 ppm. The cooking duration and temperature of 100-230ºC together contributed to decrease the cyanide concentration. Our findings concluded that Javanese applied traditional food safety management through the farmers' preference to cultivate cassava with low cyanide level, the selection of fresh roots, and the cooking methods.

Article History
Received January 22, 2022
Accepted May 17, 2022
Published June 1, 2022

Keywords
Cassava Roots,
Cyanide Concentration,
Javanese,
Traditional Cooking,
Food Safety.

1. Introduction

Since a long time ago, cassava (*Manihot esculenta* Crantz) has become a choice of staple in Indonesia, besides the common white rice. Therefore, it represents a very promising option for food diversification. Cassava root is rich in carbohydrates with low concentrations of simple sugars. Because the cultivation does not need much water, cassava roots have an important role in maintaining food security in dry or low rainfall area (1,2), where growing paddy may be difficult. Compared to other ethnic groups, many Javanese communities consume cassava as a staple food. As a result, the island of Java becomes the main source of cassava products for Indonesia (3).

Despite the popularity and benefits, nutrient intake from cassava-based foods is generally hampered by the existence of its natural cyanogen that can be chemically transformed into free cyanide. Cassava tubers contain potentially toxic levels of cyanogenic glycosides that consists mainly of linamarin (95%), which exists in all cassava tissues, and

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ISSN 2621-9468 online, DOI 10.20956/canrea.v5i1.578

lotaustralin (5%) (1). Upon consumption, linamarin is chemically decomposed into hydrogen cyanide (HCN) by stepwise hydrolysis during reaction with the enzyme linamarase (4). Consumption of cassava roots, particularly the bitter cassava that has a high concentration of cyanide may cause death especially if the tuber is not properly prepared (5). Therefore, all variants of cassava roots must be sufficiently processed and cooked to reduce the cyanide in the resulted food products.

Various governments and international organizations have established specific limit of cyanide concentration for the public to ascertain the cassava consumption safety. The Codex Alimentarius of Food and Agriculture Organization of the United Nations (FAO) suggested the cyanide concentration in cassava foods should be 10 ppm or less (6). However, various studies of cassava in Mozambique, Indonesia, and Australia demonstrated that there were only 14% of the final food products which had lower than 10 ppm cyanide. Consequently, the safety level proposed by FAO was deemed too low (7). In consideration to those factors, the Indonesian government established that the cyanide concentration in cassava-based foods should be less than 40 ppm to prevent poisoning (7,8). This limit was used as the safety reference in this study.

Although there are a large variety of existing cassava-based foods, meals, or even beverages produced by the Javanese ethnic group of Indonesia (3), there has been little documentation of their preparation and cooking procedures. Most of the cassava processing methods that have been scientifically published were based on observations in Africa. The locals in various African countries generally spend days for treating the cassava tubers to get the desired food products (9), such as by sun-drying, fermenting, or a combination of various cooking ways (10). There were some discoveries of methods to significantly remove cyanide content in a couple of hours for cassava leaves and flour (11,12). However, to date, most of the known cassava roots processing in Africa, including steaming, are still being carried out for a long duration.

On the other hand, through generations, Javanese families spend less than an hour for preparation and cooking to get the steamed cassava, the simplest form of cooked cassava roots. This is likely to be related to the local knowledge in cultivating and selecting cassava with low level of cyanide, as shown in this study by the Javanese within Malang Regency of East Java. Such knowledge is very important because in daily traditional cassava trading, the exact cultivars, hence the precise cyanide concentration of the roots (7) is generally unknown. It thus becomes of interest to investigate the details of how the Javanese traditional ways may play a role in reducing the root's cyanide concentration.

In this paper, to elucidate the important role of the Javanese traditional knowledge, the cassava roots selection, preparation, and two cooking methods applied in normal Javanese households; steaming and roasting; were simulated. It was found that both cooking methods had similar effectivity to lower cyanide level of the selected roots, even without removing the skin. The cooked roots were safe for consumption in compliance to the Indonesian safety standard of 40 ppm. The cassava exposure to high temperatures were indicated to facilitate the evaporation of HCN, which explained the effectivity of steaming and roasting within a sufficient length of time. In conclusion, Javanese traditional ways successfully prevented cassava root poisoning and may give a remarkable input to the modern food safety management.

2. Materials and Methods

2.1. Selection of Local Cassava Roots

Fresh cassava roots were obtained from small vendors in the regency and the city areas of Malang, East Java, Indonesia. Based on their flesh color, there were two types of commonly traded cassava in Malang: the white root and the yellow root. The yellow root's flesh color resembles that of butter. Although there are at least seven cultivars of cassava roots currently grown by the farmers in Malang area with cyanide concentrations from low to high (7), the sellers would only refer to them as the 'white' or the 'yellow' ones to the buyers simply because they were not fully informed on the exact cultivars. The roots were cultivated in the southern districts of Malang Regency; mainly Donomulyo, Kalipare, and Tirtoyudo; at average daily temperature of 32^{o}C and humidity of above 70%. In addition, to investigate the cyanide content of the dry roots, some of the fresh roots were let sit for three days at temperature of 25-27^{o}C which made the roots lost their moisture quite considerably.

2.2. Cassava Preparation, Steaming, and Roasting

In cassava plants, one of the parts which have the richest cyanide content is the root peel (13). Therefore, the skin of the cassava roots must be peeled before cooking. Following the Javanese ways, the skin and parts of the cortex were peeled from the selected cassava root flesh, resulting 2-3 mm thick peels which were discarded. The peeled roots were cut into 3 cm thick cross-sections. Subsequently, they were rinsed thoroughly for 2 min with fresh water, followed by steaming for 30 min at 100^{o}C in a steamer pot commonly found in normal households. Finally, approximately 0.3 g of salt (NaCl) was sprinkled evenly for every five root sections immediately after steaming. The roots were let cool until it reached about 30^{o}C before consumption. Those stepwise method was applied to both fresh and dry roots.

Steaming was also done to the unpeeled fresh root sections for 50 min with the same cooking duration and temperature as above, without the addition of salt at the end. Besides steaming, traditional roasting with charcoal bricks was applied to the unpeeled fresh cassava root. The charcoals were put on the ground and burned until they were smoldering. The root sections were put on the bricks bed and covered by more smoldering charcoals. Roasting process took 30 min with the charcoal temperature reaching approximately 230^{o}C. During roasting, the fire was kept steady by fanning. At the end, the remaining skins were discarded by peeling and the roots were let cool until about 30^{o}C before consumption.

2.3. Determination of Total Cyanide Content of Cassava Roots

This study used a picric acid method optimized for cassava roots that was developed by Bradbury et al. to measure the cyanogenic potential of the roots and their cooked products. Triplicate 100 mg samples of the white and yellow tubers, either fresh or dry, taken after each step of the preparations and cooking methods were added on top of a buffer paper placed at the bottom of a small plastic bottle. Subsequently, 1 mL of water was added, followed by a picrate paper and a screw cap lid. The bottles stood overnight at 25^{o}C. The following day, the picrate paper was taken from the plastic support and placed in test tubes with 5.0 mL water for 30 min. The absorbance of the colored solutions of each of the prepared triplicate was measured at 510 nm in a Beckman Coulter DU 700 series UV-VIS spectrophotometer. The total cyanide content was reported in ppm following the calculations of Bradbury et al (14).

2.4. Statistical Analysis

There were 24 sample types analyzed, each type consisted of three replications or triplicates. The triplicates data are presented as the mean with the standard deviation displayed in an adjacent bracket. Differences between group means were evaluated by ANOVA single factor. The F, P-value, and F critical were calculated. When F is bigger than F critical, the test was considered statistically significant, whereas P-value ≤ 0.05 confirmed that there was a difference between group means.

3. Results and Discussion

3.1. Selection and Preparation of Cassava Roots

The farmers of the southern part of Malang Regency have been growing and consuming cassava roots since a long time ago. With that habit, comes an awareness to cultivate cassava roots which have low cyanide concentrations. A 2013 study by Ginting and Widodo stated that as many as 48% of those farmers cultivated local sweet cassava variants which contain less than 50 ppm cyanide for direct consumption, whereas 19% planted both sweet and bitter variants with cyanide level higher than 50 ppm. The rest of the farmers exclusively grew bitter cassava (7). Meanwhile, across the entire nation, only five of the 14 improved varieties grown by Indonesian farmers are classified as roots with low cyanide content (7). It means that the preference to cultivate the sweet variants for direct consumption was quite unique, hence it can be said that the farmers in Malang assisted the local cassava food safety management.

In connection to that, it is believed that most cassava roots sold to common buyers were the sweet, low cyanide variants, which included the obtained white and yellow cassava used in this study. Each of the white and yellow cassava roots bought from traditional sellers had specific characteristics. As illustrated in Figure 1, the white cassava had brittle skins and the root lengths were about 15 cm (Figure 1a). In contrast, the yellow cassava had smooth skins and usually had smaller diameter compared to the white roots (Figure 1b). The yellow roots length was generally longer, sometimes even reaching about 20 cm. It was found that the yellow roots had less moisture compared to the white ones, therefore their flesh texture was tougher.

(a) (b)

Figure 1. The physical characteristics of: (a) White roots; (b) Yellow roots. The naming was based on their flesh color, and their physical characteristics helped sellers and buyers to distinguish between them.

Javanese farmers and sellers did further efforts based on their traditional knowledge to make certain that they did not distribute highly poisonous cassava roots. To reach the traditional marketplaces or sellers, the farmers took a relatively short transport route from the Regency area to the whole Malang area, usually in less than two hours. Furthermore, before selling, farmers and sellers immediately discard the roots which showed blue spots that signed cyanide accumulation. Lastly, the sellers usually reminded the buyers to cook the roots soon after buying to avoid storing them for more than two days, which would make the roots dry.

Regarding the recommended storage period to prevent the roots from drying, there is indeed a strong correlation between the water content of cassava with its toxicity: the drier the roots, the higher their cyanide level (9). During our preparation stage, it was observed that peeling the yellow cassava was more difficult than the white one because of the yellow roots' low moisture level. The possibility of cyanide excess due to insufficient peeling of the skin and cortex may contribute to the higher total cyanide content of the yellow root compared to the white one.

3.2. Cooking Methods and Estimation of Cyanide Level

The cyanide level of the fresh root sections from every stage of preparation and steaming were compared to determine their effectiveness in reducing the cyanide content (Table 1, upper). It was perceived that the high cyanide concentration in the untreated white and yellow roots may be due to the presence of the peel in the sample for measurement. The statistics for each assay with fresh white roots and yellow roots were confirmed with ANOVA single factor. It was shown that both F values were higher than the F critical numbers, signifying that the results were statistically significant (Table 1, lower). The F value for yellow cassava was considerably higher than that of the white cassava, which may indicate the notable decreases of cyanide content from the initial to final product. Additionally, the P-values were lower than 0.05, confirming that there were differences between the means of the measured groups.

For the white roots, removing the peels was shown to reduce the cyanide concentration to about a half. After rinsing, the cyanide level further decreased by two-fold to 33 ppm. However, that value was still close to 40 ppm, which is the tolerable toxicity limit in Indonesia. It was the subsequent steaming and adding salt to the root sections that lower the cyanide concentration to a safe level of 12 ppm.

Peeling and rinsing the yellow cassava root sections, on the contrary, did not lead to an appreciable decrease of cyanide. These results may be related to the difficulty in peeling the yellow roots. The high cyanide level from the peel and cortex (13) added up to make the total concentration which could not be reduced simply by 2 min rinsing. Nevertheless, steaming removed about five-fold of the cyanide concentration. Like the white variant, adding salt to the steamed yellow roots also reduce the remaining cyanide from 48 ppm to the final concentration of 18 ppm.

In natural condition, the cyanide of the roots is generated from the breaking down of the β-glycosidic bond of linamarin by the enzyme linamarase. The results are glucose and acetone cyanohydrin, which is a precursor of HCN (15). Nevertheless, the exposure of cassava to high cooking temperatures, apart from the presence of linamarin and other factors such as high pressure or the use of mineral acids, also enable the conversion of linamarin to acetone cyanohydrin (16). The free HCN as the product of the chemical reaction with heat is volatile and will readily escape to the air instead of remaining in the cassava root (9,15) because it no longer binds to the glucose ring of the linamarin that naturally resides in the roots cell.

Addition of salt (NaCl) lowered the cyanide content of the steamed fresh roots to approximately half of the preceding concentration, as shown in the last line of Table 1. A study on *gadung*, an Indonesian local tuber which also contained cyanide, stated that HCN underwent osmosis during soaking with salt water and was attracted to the Na^+ of the NaCl compound (17). In this study, the salt was added immediately after steaming when the roots were still hot. The free HCN was likely to escapes to the air as cyanide gas (15). The high temperature may also degrade HCN, and the remaining CN^- would bind to the Na^+ ion of the salt. The resulted NaCN also evaporated from the roots. Accordingly, the cyanide concentration was further reduced before the roots' temperature reached about 30°C.

Table 1. Upper table: Mean total cyanide (ppm) remaining after various stages of preparations and cooking the peeled fresh white and yellow cassava roots; Lower table: ANOVA single factor.

Treatment	Mean total cyanide (ppm) remaining after peeling, steaming, rinsing, and adding salt	
	White root[a]	Yellow root[a]
Untreated	133(2)	283(2)
Peeling	67(6)	267(6)
Rinsing	33(6)	250(3)
Steaming	23(3)	48(3)
Adding salt*	12(3)	18(3)

*[a]Standard deviations are shown in brackets; *The samples for cyanide measurement were taken when the roots temperature reached about 30°C.*

Values	ANOVA single factor	
	White root	Yellow root
F	406.69	4088.41
P-value	5.08E-11	5.11E-16
F critical	3.48	3.48

Steaming is the shortest and most common method to cook cassava roots in Java (3). Table 1 showed that it was efficacious for both white and yellow roots, although the yellow cassava had higher initial concentration of cyanide. It must be noted, however, that steaming may not be suitable as a sole method to remove cyanide in some cassava types. As reported by Montagnac et al., steaming was ineffective for African cassava variants despite being sufficient for South Pacific cassava roots (1,18).

The South Pacific climate, including Fiji (18), may resemble that of Indonesia in general. Hence, it was thought that the climate conditions in Malang Regency with its high humidity helped to control the cyanide level of the roots. In fact, it was reported that cassava grown in wet areas has lower cyanide content than those in arid lands (9). Other factors such as soil type and the presence of nutrients also played important role in determining the cassava root's moisture level, as confirmed by the Indonesian research agency for nuts and tubers (*Balitkabi*) (19).

Steaming and the step-by-step treatments, however, were not potent to reduce cyanide of the dry roots of both white and yellow types (Table 2, upper). The ANOVA single factor analysis demonstrated that both F values of the white and yellow roots were higher than F critical numbers, thus the tests were statistically significant (Table 2, lower). Both P-values were lower than 0.05, confirming that there were significant differences between the means.

The untreated dry cassava roots were demonstrated to have higher cyanide level compared to the fresh ones (Table 1, upper), particularly the yellow variant. The final cyanide concentrations were 23 ppm for dry white roots and 73 ppm for dry yellow roots which surpass Indonesian safety limit. Although 23 ppm of cyanide may still be categorized as safe, consuming those dry roots is overall not recommended to avoid the risk of accidental poisoning.

These findings confirmed that the dryness of the roots was closely related to the higher cyanide level, especially for yellow cassava that is naturally drier than the white ones. In this condition, the addition of salt did not contribute much to reduce the cyanide level because of the high cyanide content. Chemical reaction may get slower when there is an imbalance in the concentration of the reacting compounds (20), in this case the NaCl and HCN. These results were in line with the suggestions from the traditional cassava sellers to avoid consuming dry roots. Additionally, it is important to note that simple and short processing for Javanese cassava variants by the locals is also determined by the freshness of the roots.

Table 2. Upper table: Mean total cyanide (ppm) remaining after various stages of preparations and cooking the peeled dry white and yellow cassava roots; Lower table: ANOVA single factor.

Treatment	Mean total cyanide (ppm) remaining after peeling, steaming, rinsing, and adding salt	
	White root[a]	Yellow root[a]
Untreated	150(1)	348(2)
Peeling	140(5)	333(2)
Rinsing	68(3)	275(5)
Steaming	48(3)	80(1)
Adding salt*	23(3)	73(6)

*[a]Standard deviations are shown in brackets; *The samples for cyanide measurement were taken when the roots temperature reached about 30°C.*

Values	ANOVA single factor	
	White root	Yellow root
F	919.94	4041.85
P-value	8.75E-13	5.41E-16
F critical	3.48	3.48

The upper Table 3 demonstrated that steaming both fresh white and yellow cassava roots with the skin intact at 100 °C for 50 min significantly reduced the cyanide concentration to more than ten-fold, so they could safely be consumed. Those results were confirmed to be statistically significant in the lower Table 3, where the two F values were higher than their respective F critical numbers. Similar with previous results in the lower Tables 1 and 2, the P-values were less than 0.05.

The skins of both variants also got naturally separated from the flesh when the steaming was finished, so the remaining cyanide on the skins did not interfere with that of the cooked roots. An additional investigation with the picric acid method pointed out that the final cyanide levels of the skins alone were 47 ppm for the white root and 78 ppm for the yellow root from the initial concentrations of 150 and 300 ppm, respectively. It confirmed that it was the cyanide from the peels that enhance the total cyanide concentration of the whole roots, and the steaming method successfully diminish the concentration as well.

Remarkably, for both steaming as well as roasting for 30 min at 230°C, the final cyanide concentrations of the roots were close to the cyanide level of the peeled and steamed fresh roots after the addition of salt (Table 1, upper). Particularly for yellow roots, both cooking methods significantly reduced the cyanide concentration to 15 and 17 ppm, almost 20-fold lesser than the initial amount of 283 ppm. This may suggest that the peeling step can be omitted, provided the roots were thoroughly heated in sufficiently longer time.

The exposure of the roots to heat during cooking was thought to help destabilize linamarin as the predominant cyanogenic glycosides of cassava. Evidence that the time of exposure to heat is indeed important was provided by Ndam et al (9). Their review of previous studies about sun drying treatment to cassava chips pointed out that insufficient exposure to sunlight would cause enzyme linamarase to be denatured or trapped inside the root's matrix, hence the linamarin could not be converted into HCN. Such insufficiency was mainly due to the sun drying duration that was too short or the size of cassava sections that were too thick (9). In response to that, this study made sure that the steaming and roasting duration were strictly adhered to. Furthermore, the uniform thickness of the root sections was carefully measured during their preparation (section 2.2). Thus, it could be ensured that the roots got thoroughly heated during the cooking process.

Table 3. Upper table: Mean total cyanide (ppm) remaining after various stages of preparations and steaming or roasting the unpeeled fresh white and yellow cassava roots; Lower table: ANOVA single factor.

Treatment	Mean total cyanide (ppm) remaining after steaming or roasting unpeeled fresh roots	
	White root[a]	Yellow root[a]
Untreated	133(2)	283(2)
After steaming	12(2)	15(1)
After roasting	13(3)	17(3)

[a]*Standard deviations are shown in brackets.*

Values	ANOVA single factor	
	White root	Yellow root
F	2548.61	6237.93
P-value	1.63E-09	2.38E-09
F critical	5.14	5.41

4. Conclusion

Based on the results, it can be said that the Javanese ethnic group of Indonesia, represented in this study by the community of Malang Regency in East Java, adhered to their unique food safety practice to avoid poisoning. There were three main steps that they followed: 1) the cultivation cassava with low cyanide level, 2) the selection of fresh roots, and 3) the cooking methods. During cultivation, the local climate conditions such as temperature and high humidity helped to regulate the roots' moisture level, thus preventing the accumulation of cyanide. Moreover, this study discovered that the exposure of high cooking temperature, the adequate duration of steaming or roasting, and the addition of salt all played crucial role in the breakdown of linamarin, subsequently enabling the cyanide gas evaporation from the roots. Consequently, the final concentrations of cyanide of the roots were well below the acceptable safety limit in Indonesia. Those treatments, however, failed to thoroughly remove cyanide from dry roots. Hence, the freshness of the roots was also a crucial factor that could not be neglected. All in all, the practice of Javanese cassava food safety ascertained that the cassava food products were safe for consumption, despite the limited information about the exact variant of the roots sold by traditional sellers. It should be noted, however, that roasting gets increasingly less popular due to the time-consuming preparation. There was also a fear of carcinogens from the smoke and the burnt parts of the root. Since steaming the unpeeled roots for 50 min led to approximately similar results with roasting, it can be recommended as a more feasible and less carcinogenic substitution.

Acknowledgements

This article could not have been completed without the valuable contribution of local cassava sellers in the Regency and City of Malang for supplying the cassava roots and providing information. Deep gratitude also goes to Professor William Foley and Dr. Janet Elliott of Konzo Prevention Unit of Australian National University (ANU) for their generous share of knowledge and discussion. This research was self-supported.

Author Contributions

W.L.A. conceived the research outline and visualized the data. All authors designed the research methodology. W.L.A. and S.H. carried out the investigation. W.L.A wrote and prepared the original draft. S.H. and A.K. validated the data, reviewed, and edited the manuscript. A.K. ran the project administration and supervision.

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Data Availability Statement

Available data are presented in the manuscript

Conflicts of Interest

The authors declare no conflict of interest.

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