

Cyanide in Cassava Varieties and People's Perception on Cyanide Poisoning in Selected Regions of Tanzania

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Abstract

Cassava, an important food crop in the tropical regions of the world, is known to carry varying levels of cyanogenic glucosides that are potential poison to humans. In Tanzania, cases of cyanide poisoning have been reported in many cassava producing areas. This study was launched to quantify cyanide in fresh tubers of so called “sweet” cassava varieties and to gauge peoples’ perception on cyanide poisoning in Kagera and Morogoro regions. The study employed a questionnaire survey and a cross-sectional research design to identify different cassava varieties and their cyanide content using alkaline titration method. Findings showed that cyanide content in all of the analyzed tubers were above the internationally accepted levels in human consumables. Some sweet varieties were found to be wrongly classified as sweet because their cyanide content was above acceptable limits. For the same variety tubers sampled from a lowland area had significantly higher ($P < 0.01$) cyanide content than those from a highland point. It was also found that the upper (slippery) parenchymal tissue had more cyanide content ($P < 0.05$) than the inner tissue. Nearly 80% of the studied population was unaware of cyanide poisoning, its health effects and how to reduce cyanide content prior to consumption. It is concluded that consumption of raw cassava tubers can lead to undesirable health effects despite of some of them being categorized as sweet. The public should be sensitized on the issues of cyanide in cassava and should avoid consuming raw cassava tubers as preventive measures against cyanide poisoning.

Keywords: cassava varieties, cyanide levels, cyanide poisoning

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a perennial crop native to tropical America (Allen, 1994) and an important and cheap source of carbohydrate in tropical and sub-tropical regions, particularly in Sub-Saharan Africa. The cassava plant grows faster compares to other crops (Nhassico *et al.*, 2008; Tivana *et al.*, 2014; Ubwa *et al.*, 2015) and has remarkable ability to withstand harsh climatic conditions. These two qualities have made the diverse edible varieties of cassava to be an outstanding crop that saves at least 500 million of human lives from hunger worldwide. About 56% of the world’s cassava production has its source in Africa and Tanzania is among the leading producer countries in the world (FAO, 2013). Apart from being a popular staple crop and a superb source of carbohydrates and minerals (Mburu, 2013; Mercola, 2016), cassava carries a potential danger of cyanide poisoning (Babalola, 2014), as it contains cyanogenic glycosides, mainly linamarin: 2- β -D-glucopyranosyloxy-2-methylpropane nitrile, and lotaustralin: 2- β -D-glucopyranosyloxy-2-methylbutyronitrile (Idible, 2006). On hydrolysis in the human gut, the cyanogens produce hydrocyanic acid which is toxic (Tivana *et al.*, 2014). Cyanide is responsible for several health complications such as Konzo disease, thyroid goiter and tropical ataxic neuropathy, TAN (Kobawila *et al.*, 2005), incidences of cretinism, stunted growth in children and deaths (Nhassico *et al.*, 2008), epilepsy (Ngugi *et al.*, 2013) as well as behavioral and emotional abnormalities in children (Kariuki *et al.*, 2017).

Risk factors associated with cyanide poisoning include: the existence of a large number of cassava varieties (bitter and sweet) which differ in cyanide levels, stage of maturity, soil type (Cardoso *et al.*, 2004; Famurewa and Emuekele, 2014; Ubwa *et al.*, 2015) as well as the habit of consuming raw cassava tubers by some communities. Although cyanide levels in cassava tubers can be reduced using simple traditional methods such as boiling, roasting, drying, grating, soaking and fermentation (Ernesto *et al.*, 2002; Nzwalo and Cliff, 2011), consumption of raw cassava tubers is being practiced probably due to lack of awareness of potential dangers of cyanide poisoning. Furthermore, local classification of cassava varieties as “sweet” (i.e., non-poisonous) has added to the complacency in employing the simple treatments to reduce cyanide levels in tubers before consumption. This is because even those cassava cultivars considered sweet have been a source of disaster to humans in East Africa (Mburu *et al.*, 2011).

The current study was therefore carried out to quantify levels of cyanide in raw cassava tubers of various varieties cultivated in Kagera and Morogoro regions and gauge people’s knowledge and perception on cyanide poisoning. Findings from the study were expected to shed more light on cyanide levels in different cassava varieties, a prerequisite for formulation of proper advice against cyanide poisoning and its associated health effects.

2. Materials and Methods

2.1 Research Site

The study was done in Bukoba Rural and Missenyi districts of Kagera Region and in Morogoro Municipality and Mvomero district of Morogoro Region, Tanzania. In the two regions, cassava is widely grown and consumed raw in addition to being a staple food. Moreover, cases of cyaniding poisoning as well as indicators of cyanide poisoning in Kagera and Morogoro regions were another reason of undertaking the study in the two regions. Kagera region is located in the northwestern corner of Tanzania on the western shore of Lake Victoria, lying between 1°00’2.45”S, 30°25’32.41”E with the elevation of 1,200 m above sea level (MASL). Morogoro region is located in eastern part of Tanzania; lying between 6°41’15.67”S, 37°39’40.39”E at an average altitude of 525 MASL. Determination of cyanide levels in the sample cassava tubers was done at the Food Science Research Laboratory, Sokoine University of Agriculture (SUA) Morogoro, Tanzania.

2.2 Study Design and Questionnaire Survey

This study used cross-sectional design and purposive inclusion of participants (cassava growers and consumers) to collect responses from 386 participants through administration of a structured questionnaire. The number of participants was arrived at by employing Smith’s formula (Smith, 2013) which is only applied to unknown or too large a population. This survey assisted in identifying (by local names) the “sweet” cassava varieties grown in Kagera and Morogoro regions as well as obtaining people’s perception on cyanide in cassava tubers and its poisoning effects with respect to cassava consumption.

2.3 Sampling of Cassava Tubers

Following identification of common cassava sweet varieties, simple random sampling was employed to obtain twelve sample varieties that were used for the cyanide quantification study. From these 12 sample varieties, 66 fresh mature tubers were collected in such a way that each variety was represented by not less than five tubers each obtained from a different farm in the study area. Furthermore, tubers of three sample varieties were purposively collected from highland (Magadu Ward) and lowland (Mzinga Ward) areas of Morogoro Municipality for assessment of any effects of altitude on cyanide content. All the tubers from selected locations were transported to the laboratory within two days of their harvesting to meet their limited shelf life.

2.4 Quantification Cyanide Levels

At the laboratory, the tubers were preserved in a refrigerator (at 4°C) until analysis. The cyanide levels were determined using alkaline titration method (AOAC, 1995). Briefly, tubers were washed and then peeled to obtain the parenchyma. The parenchyma was longitudinally cut into several portions, which were ground using an electric blender to obtain ground parenchyma tissue from which two portions each weighing 20 g were used. Each of the portions was placed into 800 mL Kjeldahl flask and then mixed with 200 mL distilled water. The mixture was left to stand for at least two hours for complete enzymatic process; this was followed by steam-distillation of the mixture to collect 150 mL distillate in NaOH solution (0.5 g in 20 mL H₂O) contained in a flat-bottomed flask. To 100 mL of the distillate, 8 mL 6N NH₄OH and 2 mL 5% KI solution were added and then titrated with 0.02N AgNO₃ using micro-burette. The average titre volume for the results obtained from the two 20 g - portions of the sample tuber was recorded. Eventually, cyanide content for each average titre volume was calculated by using the formula for alkaline titration method: $1\text{ mL } 0.02\text{ N AgNO}_3 = 1.08\text{ mg HCN}$ (AOAC, 1995). The calculated values were in turn used to work out mg (HCN) per kg of fresh cassava.

2.5 Distribution of Cyanide Levels in the Parenchyma

Distribution of cyanide in cassava tuber parenchyma was determined using three samples each representing a different variety. From each sample, 20 g were scratched off from the upper (slippery) tissue and 20 g from the adjacent inner tissue of the tuber parenchyma. Each of these portions was placed into 800 mL Kjeldahl flask and then mixed with 200 mL distilled water and underwent the remaining steps of the procedure as already described above to obtain the titre volume with eventual determination of cyanide level for each titre volume.

2.6 Statistical Analysis

The questionnaire data were handled by Microsoft Excel (2010) analyzed using Statistical Package for Social Sciences (SPSS, 2015) to calculate percentage responses, means and standard deviations. ANOVA was also carried out to test different hypotheses.

3. Results

3.1 Cassava Varieties Grown in Kagera and Morogoro Regions

Fifty two common sweet cassava varieties (their local names in capital letters) were identified; 22 from Morogoro and 30 from Kagera regions, as presented in **Table 1**. The most mentioned varieties were BUKARAZA (Kagera Region) and BETAUJE (Morogoro Region), whereas the least common varieties in the two regions were SILA and MPERA respectively.

Table 1. Cassava varieties grown in Kagera and Morogoro regions including frequency and percent of variety's turns of mention

<i>Kagera region</i>			<i>Morogoro region</i>		
<i>Cassava variety</i>	<i>Frequency of mention</i>	<i>Percent (%)</i>	<i>Cassava variety</i>	<i>Frequency of mention</i>	<i>Percent (%)</i>
BUKARAZA	125	67.9	BETAUJE	107	52.9
RUSHULA	113	61.4	NYACHILO	95	47.0
KATAAKYA	102	55.4	KIGOMA-TANGA	85	40.1
PIKIPIKI	87	47.3	KIKANIKI	75	37.1
KAEMPU	86	46.7	MOSHI-WA-TAA	72	35.6
SUNGUSUNGU	85	46.2	SIGARA-BARIDI	68	33.7
SHELEKERA	82	44.6	KIBAHA	65	32.2
NJUBU	81	44.0	SIGARA-MWEUPE	62	30.9
RUTUKU	77	41.8	MWALI-MWEUPE	61	30.2
MAREKANI	68	36.9	SUPER-TALL	58	28.7
AKIBA	67	36.4	MZURI-KWAO	56	27.7
KASHANJE	57	30.9	KIBANGA-MENO	54	26.7
KONYU	55	29.9	MZUNGU	50	24.8
KARANDILIRA	55	29.9	MWANGA	45	22.3
SEZARIO	50	27.2	MNDUNGA	36	17.8
MAMA-ASHA	46	25.0	MTWIKE	35	17.3
KAGINGO	45	24.5	MWARUSHA	33	16.3
MBARA	45	24.5	KISWAHILI	27	13.4
KOMUBEGI	40	21.7	CHELEMA	25	12.4
MANIMAJEJE	40	21.7	KIBIBI	22	10.9
NAZARETI	40	21.7	KISAMBAA	20	9.9
MPOROGOMA	37	20.1	MPERA	15	7.4
JOJIA	36	19.6			
KINOGOFU	35	19.0			
KACHALI	35	19.0			
KYA-MWANZA	33	17.9			
KWATAMPALE	33	17.9			
GONYA	31	16.8			
MATOKE	30	16.3			
SILA	22	11.9			

3.2 Cyanide Levels in Cassava Tubers and Varieties Sampled From Different Areas

The 12 sample varieties used for cyanide analysis included PIKIPIKI, SHELEKERA, KATAAKYA, SUNGUSUNGU, AKIBA, KAEMPU and RUSHULA (Kagera Region), KIKANIKI, MZURIKWAO, MWANGA, NYACHILO and KIBAHA (Morogoro Region). Cyanide levels for the 66 cassava tubers collected from Kagera (38 tubers) and Morogoro (28 tubers) regions are presented in **Table 2**. The highest determined cyanide level (mg/kg fresh weight) for each variety was 226.80 (PIKIPIKI), 190.35 (SUNGUSUNGU), 117.05

(KIKANIKI), 116.64 (MWANGA), 100.85 (MZURIKWAO), 85.05 (AKIBA), 77.76 (KATAAKYA), 75.33 (RUSHULA), 66.83 (SHELEKERA), 64.80 (KIBAHA), 58.73 (KAEMPU) and 47.39 (NYACHILO).

Table 2. Mean tuber cyanide (HCN) content (mg/kg fresh weight) in selected 12 cassava varieties from Kagera and Morogoro regions

Region	Cassava variety	No. of samples	Mean	STDev	SEM*	Min.	Max.
Kagera	PIKIPIKI	5	114.56	64.25	28.73	66.42	226.80
	SHELEKERA	5	51.02	18.06	8.09	20.66	66.83
	KATAAKYA	5	55.04	20.93	9.38	30.38	77.76
	SUNGUSUNGU	5	108.96	50.50	22.58	56.70	190.35
	AKIBA	5	49.76	26.19	11.70	19.85	85.05
	KAEMPU	4	51.73	7.56	6.26	42.10	58.73
	RUSHULA	9	44.84	21.13	7.99	24.30	75.33
Morogoro	KIKANIKI	6	64.80	30.44	12.43	40.50	117.05
	MZURIKWAO	6	59.06	28.50	11.63	36.45	100.85
	MWANGA	6	73.17	26.00	10.66	35.64	116.64
	NYACHILO	5	33.13	10.11	4.52	22.68	47.39
	KIBAHA	5	46.74	12.56	5.62	31.19	64.80

*SEM = standard error of means

3.3 Altitude Effect on Cyanide Levels in Three Cassava Varieties

Comparison of cyanide content for the three varieties (KIKANIKI, MZURIKWAO and MWANGA) sourced from both highland and lowland areas is presented in Figure 1. For each cassava variety, there was significantly higher ($P < 0.01$) mean cyanide content in tubers collected from lowland areas (82.62 mg/kg) compared to those from highland areas (48.74 mg/kg).

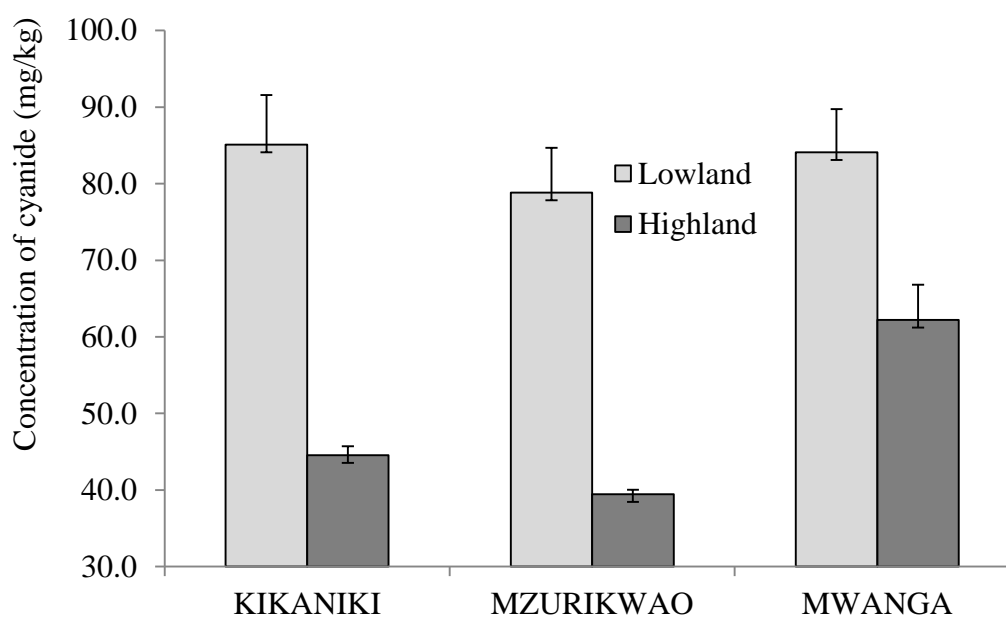


Figure 1. Effect of altitude on concentration of cyanide in selected cassava variety tubers

3.4 Distribution of Cyanide Between the Upper and Inner Tissue of Cassava Parenchyma

The results for the distribution of cyanide in the upper tissue and inner tissue of the cassava parenchyma for three tested varieties (MZURIKWAO, KIKANIKI and MWANGA) are summarized in **Figure 2**. The upper slippery layer had significantly higher ($P < 0.05$) cyanide concentrations than the inner parenchyma for each of the three cassava varieties that were analyzed.

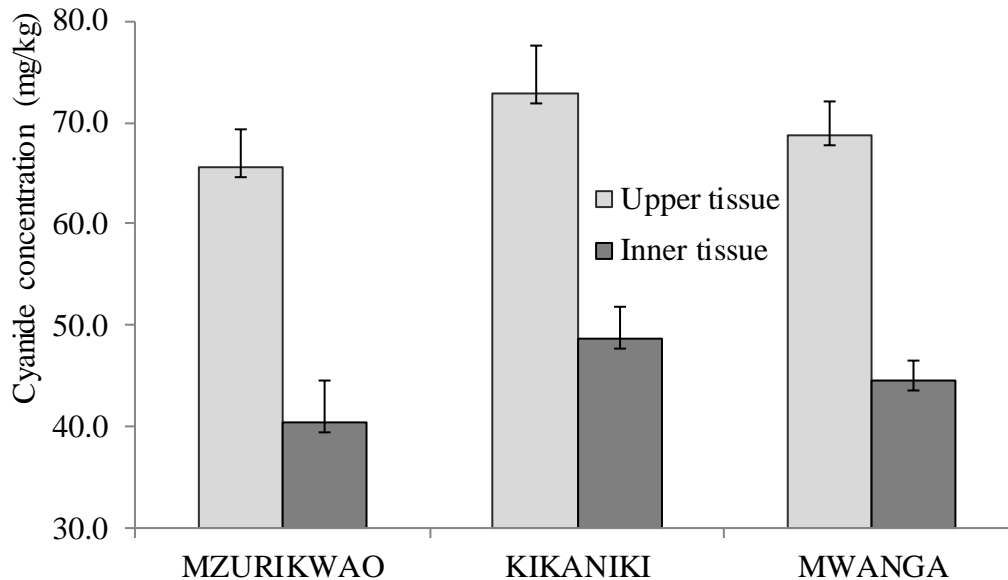


Figure 2. Distribution of cyanide between upper slippery and inner parenchyma of the three selected cassava tubers

3.5 Peoples' Awareness About Cyanide and Its Poisoning Effects

Peoples' awareness on different aspects about cyanide and its effects to human health, namely, cyanide quantification method, cyanide depleting methods, cyanide poisoning effects and presence of cyanide in sweet and bitter varieties are summarized Figure 3. About 60% of the respondents were aware of poisoning by bitter cassava varieties whereas less than 15% knew of poisoning by the so called sweet varieties. Whereas cyanide poisoning effects and methods for depleting cyanide levels in cassava were equally known by the respondents, none of them were aware of any cyanide quantification methods.

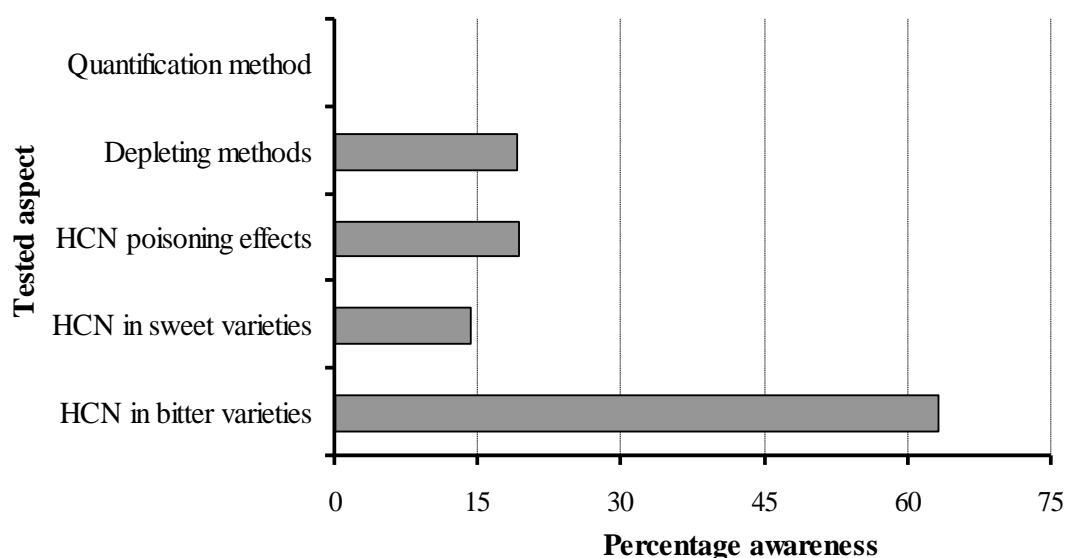


Figure 3. Peoples' awareness on different aspects of cyanide poisoning from consumption of cassava

4. Discussion

4.1 Cassava Varieties Grown in Kagera and Morogoro Regions

The survey showed that different varieties were grown by considering one or a combination of qualities including palatability, maturity attainment duration, productivity, resistance to diseases and tuber shelf life. Growth to maturity differed from one variety to another, some maturing within six months like KATAAKYA while others maturing in a year or longer such as RUSHULA. This finding was in line with the observations made by Allem (2002) and Montagnac *et al.* (2009) that cassava cultivars differ in their ability to tolerate pest and diseases, yield, nutritional and cooking qualities of food products as well as maturity attainment. It was also noted that, the meanings of some local names of cassava varieties hint to the qualities of such varieties. For instance, SHELEKERA (“hide for”) signifies productivity; SUNGUSUNGU (“fierce local guard”) hints to bitterness; KATAAKYA (“flowers not”) signifies early maturity; MATOKE (“like banana fruit”) gives the idea of ease to cook; and KONYU (“salty”) refers to palatability. One respondent commented that the same variety may exhibit inconsistent maturity age due to environmental factors such as climate and soil type. For instance, KIBAHA variety was cited as taking 8 months to mature in Kibaha (Coast Region), but taking longer when grown in the highlands of Morogoro region. On SUNGUSUNGU, a note was made that its harvest should be delayed otherwise one should be ready to bear with its bitterness in its early maturity. This is in line with the previous observation that cyanide levels decrease as cassava plants age (Hidayat *et al.*, 2002; Chotineeranati *et al.*, 2006).

4.2 Cyanide Levels in Cassava Tubers and Varieties

All the tested tubers contained cyanide with levels ranging from 20 - 227 mg/kg for Kagera varieties and from 23 - 117 mg/kg for Morogoro varieties. These levels were all above the acceptable limit of 10 mg/kg in human consumables (FAO, 1977). By considering mean

cyanide content of 50 mg/kg as the cutoff point between sweet and bitter tubers (FAO, 1977; Mercola, 2016), only four varieties (AKIBA, RUSHULA NYACHILO, and KIBAHA) could be regarded as sweet. With the exception of the varieties NYACHILO, SUNGUSUNGU and PIKIPIKI, the remaining varieties contained samples in both categories, suggesting that a variety can exist in both sweet and bitter forms. With regard to cyanide levels in cassava tubers, the findings of this study are in favor of authors who hold that acyanogenic cassava varieties are non-existent and cyanide level in all cassava tubers are above the accepted amount in human consumables (Bradbury and Holloway, 1988; White *et al.*, 1998; FAO, 2007). Human consumables containing cyanide levels above 10 mg/kg are not eligible for direct consumption unless appropriate methods for depleting cyanide are employed (FAO, 2007). Moreover, the noted inconsistency of cyanide levels within samples of the same variety means that cyanide level in one sample tuber can in no way be used as a standard for other samples of the same variety collected from different geographical areas. In other words, the same variety can exist in both sweet and bitter forms due to factors that affect cyanide levels in cassava including water stress (Tan, 1995; Bokanga *et al.*, 2004; Gitebo *et al.*, 2009), soil type (CIAT, 1989; Ekanayake, 1994; CHU, 2015) and application of fertilizers (De Bruijn, 1973; Endris, 1977; Wheeler *et al.*, 1990; Cuvaca *et al.*, 2015).

The observation that some sweet cassava varieties grown in Kagera and Morogoro regions differ significantly in cyanide content concurs with observations made by previous researchers that although all cassava cultivars/varieties contain cyanogenic glycosides, a wide variation in the concentration of cyanogens exists among different cultivars (Cardoso *et al.*, 2004; CIAT, 2007). The categorization of sample tubers and varieties into sweet and bitter lines calls for conscious consideration of methods appropriate for reducing cyanide in consumables to acceptable levels. Tubers in sweet cassava form need be boiled prior to human consumption (Cardoso, 2004; FSANZ, 2004; Ubwa *et al.*, 2015). For bitter ones, a more effective process for depleting cyanide than mere boiling is required before being cooked for human use (Ernesto *et al.*, 2002; Cardoso *et al.*, 2004; Nzwalo and Cliff, 2011). Whereas bitterness in taste is not always a guarantee of cyanide level (Dufour, 1994) as this could stem from chemicals other than cyanide (Bokanga, 1994), there are cases in which varieties known to be sweet have tubers with high cyanide content disqualifying them to be called sweet (CIAT, 1989; Ekanayake, 1994; Tan, 1994). In other words, neither taste nor name of variety is a sure method for identifying poisonous and non-poisonous cassava varieties.

4.3 Effect of Altitude on Cyanide Level in Cassava Tubers

Our current findings on the effect of altitude on mean cyanide level in cassava tubers concur with those reported by Oluwole *et al.*, (2007) in a similar study, which compared cyanide content of Nigerian and Tanzanian varieties obtained from varying altitudes. Stress factors such as high temperature and drought in the lowland areas may account for higher cyanide glycosides content in tubers of the same variety raised/cultivated in lowland areas. In our questionnaire survey we also found that in Morogoro municipality, most cassava tubers consumed raw are grown in highland parts of the region such as in the slopes of Uluguru Mountains.

4.4 Distribution of Cyanide Between the Upper and Inner Tissue of Cassava Parenchyma

The results revealed significantly higher ($P < 001$) cyanide content in the slippery upper issue than in the inner parenchyma suggesting that cyanide is not evenly distributed within the tuber. Several methods have been employed to reduce cyanide levels in cassava tubers (Ernesto *et al.*, 2002; Nzwalo and Cliff, 2011). In the current study, the interest was focused on finding out if the practice of scratching off the slippery tissue of sweet cassava tuber (evident in Kagera region) could significantly reduce cyanide content in the tuber. This study has clearly proven that the upper parenchyma tissue is richer in cyanide than the inner tissues; thus justifying the habit of scratching of the slippery upper tissue prior to consumption or cooking cassava tubers.

4.5 People's Awareness About Cyanide and Its Poisoning Effects

The finding that about 80% of the respondents in this study were ignorant about the effects of cyanide poisoning including the knowledge of bitter and sweet varieties was a clear indication that consumption of raw cassava can have potential health concerns. Peoples' habit of consuming raw cassava tubers in the study area was therefore mostly cultivated by lack of awareness about cyanide in cassava and its poisoning effects. According to a respondent in the current study, a fatal case of cyanide poisoning happened in Kauzeni, Mvomero District in 2016. Ravindra (2007) supports the fact lack of education is one of the major factors contributing to neurotoxic disorders, namely, lathyrism, Konzo, and TAN. The mentioned ways commonly used by people to identify poisonous cassava tubers, such as previous experience on the variety and tasting are misleading. It has been shown that cassava varieties can display inconsistency of cyanide level due to different factors (Tan, 1994; Ekanayake, 1994; CIAT, 1989) and the same variety can exist in both sweet and bitter forms. Moreover, the degree of sweetness or bitterness does not necessarily foretell the degree of cyanide level in cassava tubers (Bokanga, 1994; Dufour, 1994). It is thus risky to consume raw cassava tubers whose cyanide level is unknown (Ubwa *et al.*, 2015; FSANZ, 2004).

5. Conclusions

It is concluded that all cassava tubers that were analyzed in the current study had cyanide content above the internationally acceptable levels and thus consumption of such tubers in their raw state can lead to poisoning effects. Since the practice of characterizing a cassava variety as sweet or bitter can be misleading, measured cyanide levels should be used as a basis for categorizing cassava varieties in terms of their cyanide glycosides content. The finding that the upper (slippery) parenchyma tissue contains more cyanide glycosides than the inner tissue confirms that the practice of scratching off this slippery layer prior to boiling of tubers is not superfluous and should be promoted as one of the cyanide depletion methods. Availing people with new cassava varieties should go hand-in-hand with provision of education on cyanide poisoning effects as well as appropriate methods for depleting cyanide to acceptable levels for human consumption. Development of simple, cheap and rapid techniques to quantify cyanide in cassava tubers is recommended.

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Conflict of interest

No conflict of interest associated with this work.

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