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Tuber yield, morphology, and chemical properties variability of sweet cassava germplasm

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Abstract

In Indonesia, the superior sweet cassava varieties are still limited due to the situation on which the majority of the superior varieties -bitter varieties- are used as industrial raw material until now. Therefore the availability of new high yielding of sweet cassava varieties is still needed. Assembling varieties requires the support of germplasm that has identified its superiority. The research objective was to evaluate tuber yield, morphology, and physico-chemical properties of cassava tuber from sweet cassava germplasm. A total of 75 accessions were characterized in Jambegede research station in February-November 2016, using Randomized Block Design. Variables observed included plant height, number of plants at harvest, harvest index, number and weight of tuber yield, and starch content. Physico-chemical analysis of tubers was carried out on 15 accessions with high tuber yields. Plant height at harvest was 393.2 cm in average. There were 10 accessions of sweet cassava with high fresh tuber yields ranging from 36.61 ton.ha^{-1} to 61.64 ton.ha^{-1}, i.e MLG 10366, MLG 10365, MLG 10318, MLG 10197, MLG 10325, MLG 10341, MLG 10018, MLG 10279, MLG 10298, and MLG 10263. Physico-chemical analysis showed that the average of HCN content was 9.40 ppm, moisture content of 59.5 %, starch content of 28.8 % wb, and amylose content of 11.0 % wb. The bitter cassava with steamed tuber texture not cracked had relatively higher levels of HCN and water content, which was 82.88 ppm and 74.8 %, while the starch and amylose content was relatively lower (15.8 % wb and 5.5 % wb).

INTRODUCTION

Cassava is an important food commodity for more than 800 million people worldwide (Food and Agriculture Organization, 2013) and in the tropical area, cassava is the main carbohydrate source after rice and maize. Cassava ensures food security which can be stored in the soil for a period of up to two years. Most people need cassava as fresh food, so the availability of sweet cassava varieties is preferred. In addition, cassava can be processed into various food and non-food products, such as starch, flour, drinks, animal feed, biofuels and textiles. For these needs, bitter cassava varieties are not a problem, because the compounds that cause bitter taste (HCN) are soluble in water and will be lost during the processing process.

Cassava is generally categorized as bitter or sweet cassava, depending on its cyanide content. Clones with HCN levels < 100 mg.kg^{-1} (wb) are called sweet cassava while those with HCN levels of 100 mg.kg^{-1} to 500 mg.kg^{-1} (wb) are bitter cassava. Cassava is classified as sweet if the HCN content is less than 100 mg.kg^{-1} (wb) and it is bitter providing that the HCN content is more than 100 mg.kg^{-1} (wb) (Vieira et al., 2011, Hahn et al., 1988). On the other hand, based on Ndubuisi and Chidiebere, (2018), cassava is categorized as sweet (actually not bitter) if the HCN produced is about 20 mg of cyanide per kg of fresh root, while it is bitter if it produces more than

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50 times the HCN. Sweet cassava can be processed simply by peeling the skin and cooking it (roasted, boiled or fried), whereas bitter cassava requires a more complicated process. However, with traditional techniques, bitter taste can be reduced because the compound is soluble in water, and can be processed as delicious as sweet cassava.

According to Laya et al., (2018), the physico-chemical, functional, and sensory properties of gari (one of the processed cassava products in Nigeria) were influenced by age, harvest season of cassava, and variety. Varieties, harvest age, and storage duration affect the cassava cooking quality. Chisenga et al., (2019) reported that variety effect on the quality traits was significant which suggested that variety could be targeted as the basis of selecting cassava with potential to produce required quality characteristics. Through the physiological process of growth and the process of substance accumulation and mobilization, these factors influenced the chemical composition of tubers. During tuber storage, the starch content may decrease by 1 % per day. This is caused by the conversion of starch to total sugar (an increase in total sugar content) and an increase in the tuber respiration process (Sánchez et al. 2013) .

Most of the superior cassava varieties in Indonesia have high starch content with a bitter tuber taste. High yielding varieties that have high starch content and sweet taste is limited. The bitter taste of tubers makes farmers less free to sell their produce in the public market. Farmers can only sell to factories that frequently purchase the cassava at low prices during the peak season. Therefore, the availability of new high-yielding varieties with high starch but not bitter tubers are still needed. Assembling varieties requires the support of germplasm that has identified its superiority. Therefore this research is important to carry out. The research objective was to evaluate tuber yield, morphology, and physico-chemical properties of cassava tuber from sweet cassava germplasm.

MATERIALS AND METHODS

The experiments were carried out at Jambegede Research Station from February to November 2016, using a randomized complete block design with two replications. The treatment used were 75 accessions of cassava. Each accession was planted on a plot measuring 1 m × 5.6 m with a spacing of 1.0 m × 0.70 m (8 plants per plot). Fertilizers used were 750 kg.ha^{-1} Phonska + 100 kg.ha^{-1} Urea. The fertilizers were given three times, at the age of 2, 6, and 10 weeks. They were given by immersion in the soil around the plant with a distance of 10 cm. Weeding, pest and disease control, and the addition of irrigation were carried out optimally, following the conditions in the field. Harvesting of tubers was done at the age of 9 months.

Parameters observed were plant height (age 3, 6, and 9 months), score of red mite and mealybug pests attacks. At harvest time, the number and weight of tuber yields, dry matter and starch content with specific gravity methods were observed. The morphological characteristic description refers to Fukuda et al. (2010).

The starch content and dry matter content of fresh tubers were estimated by the specific gravity approach (X) (Teye et al., (2011), weighing 3 kg to 5 kg of fresh tubers in the air (Wa), then weighing in water (Ww). Specific gravity (X) is calculated using the equation:

$$X = \frac{Wa}{(Wa - Ww)}$$

Note:
Wa = weight of tubers in the air
Ww = the weight of tubers in water

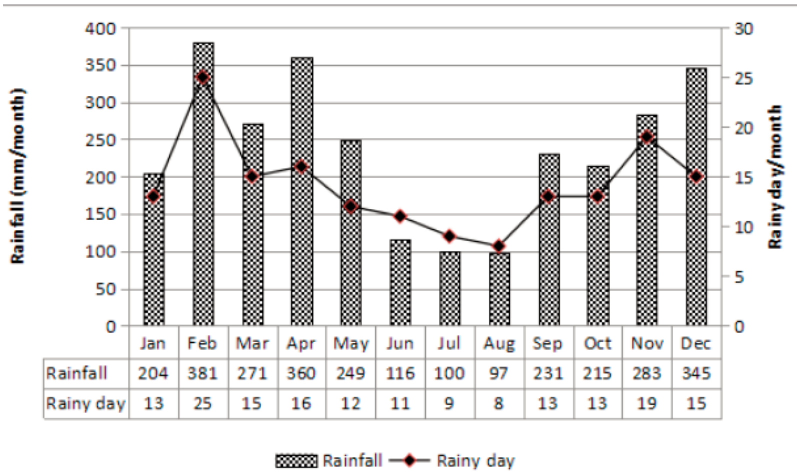
Furthermore, the dry matter content (DM) and starch content (SC) of the tuber were predicted using the equation:

DM (%) = 158.0X – 142.0
SC (%) = 112.1X – 106.4

The data obtained were analyzed for variance using the F test of α= 5 % to find out whether there were significant differences among the treatments. If the results of the F test show significant differences, the test will be continued with the LSD test at α= 5 %. About 15 accessions (most of which have high yield potential and one accession as a check) were analyzed for water content, dry matter content, HCN content, starch and amylose content in Balitkabi Food Chemistry Laboratory - Malang.

RESULTS AND DISCUSSION

The Jambegede Research Station has a C3 (Oldeman) climate type with an average rainfall of 2,300 mm and a rain frequency of 125 days per year



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	204	381	271	360	249	116	100	97	231	215	283	345
Rainy day	13	25	15	16	12	11	9	8	13	13	19	15

Figure 1. Rainfall data and rainy days every month in 2016 at Jambegede research station, planting season 2016.

(Balai Penelitian Tanaman Aneka Kacang dan Umbi, 2017). When the experiment took place, rainfall occurred in higher intensity and frequency than usual, reaching 2,852 mm and 169 rainy days per year. Rainfall > 200 mm per month occured in the first three months of growth. Three months afterwards there was still about 100 mm per month of rain, and at > 6 months (tuber enlargement phase) until the harvest, rainfall increased again to > 200 mm per month (Figure 1). According to Food and Agriculture Organization (2013), in areas with limited rainfall, with an average annual rainfall of 400 mm, cassava plants can still grow. However, to obtain optimal results, higher rainfall is required. It is known based on the results of research in Thailand that with a rainfall of about 1,700 mm during a period of four to eleven months after planting, the maximum tuber yield can be achieved.

In the initial phase of the experiment, the growth of cassava plant in 2 months after planting were very good; 100 % of the plant canopy covered the soil. The morphological performance of plants varied, according to the characteristics of each accession. The symptoms of white mealy bug and red mite attacks were low and the symptoms did not show any diversity. Mealy bugs only attacked multiple accessions with attacked scores of < 1. While red mites (*Tetranycus urticae*) attacked scores range from 0.5 to 1.5 (average 0.8). Rain that occured every month caused the growth and development of these two pests to be low. At a very high population density of mealy bug, and as it is usually the case in dry season, the attack causes the shoots to curl, book segment to shorten, and plant to become stunted (Wyckhuys et al., 2018). Indiati (2012) reported that varieties/clones with high leaf moisture content (more than 70 %) tended to have a low rate of mite infestation. The red mite pest control technique considered effective is the use of tolerant cassava varieties to reduce yield losses.

The results of the analysis of variance showed that all observed variables were significantly different on 1 % and 5 % F test (Table 1). The plant height when the plants were 3 months old ranged from 154.2 cm to 233.3 cm (average 187.6 cm). At 6 months old, it rose sharply to 290.8 cm to 399.2 cm (average 350.9 cm) and at the age of 9 months it slightly increase to 322.5 cm to 456.7 cm (average 393.2 cm). The performance of plant height from all accessions at the age of 3, 6 and 9 months is presented in Figure 2.

The number of plants harvested per plot ranged from 4–8 plants (average of 7.7 plants per plot). The causes of dead plants were the attack of root rot disease and humid environmental conditions. Whereas the number of plants that fell down ranging from 0 to 8 plants per plot (average 2.2 plants per plot). Stover weight observed at harvest ranged from 4.7 kg – 13.2 kg (average 8.7 kg per plant) (Table 2). The soil condition that was always moist in each phase of growth caused the excessive plant canopy growth. In addition, plants that fell down were caused by the blowing of strong winds that whacked plants when they werearound 6 months old. The plants that fell down were the accessions whose shoots were very vigoruous and sensitive to

Table 1. F test result and sum of square in the analysis of variance on the growth variable of cassava germplasm accession. Jambegede Research Station, planting season 2016

Variables	Replication	Treatment (accessions)	Sum of square	CV (%)	LSD α= 5%
Plant height 3 MAP (cm)	**	**	234.78	8.17	30.5
Plant height 6 MAP (cm)	ns	**	352.98	5.35	37.4
Plant height 9 MAP (cm)	**	**	630.92	6.39	50.5
Number plant per plot at harvest	ns	*	0.35	7.64	1.20
Shoot weight (kg per plant)	**	**	0.82	20.70	1.80
Harvest index#	ns	**	0.72	15.72	1.69
Number of tuber per plot#	ns	**	1.73	17.32	2.62
Tuber yield (kg per plot)#	ns	**	0.47	18.26	1.37
Tuber yield (ton.ha^{-1})#	ns	**	0.85	18.55	1.84
Starch content (%)	ns	**	5.35	11.93	4.61
Dry matter content (%)	ns	**	10.66	9.17	6.51

Remarks: MAP = month after planting; The (#) sign means the data were transformed first with √(x+0.5), ns = no significant different, (*) = significantly different at α= 5 %, and (**) = significantly different at α= 1 %

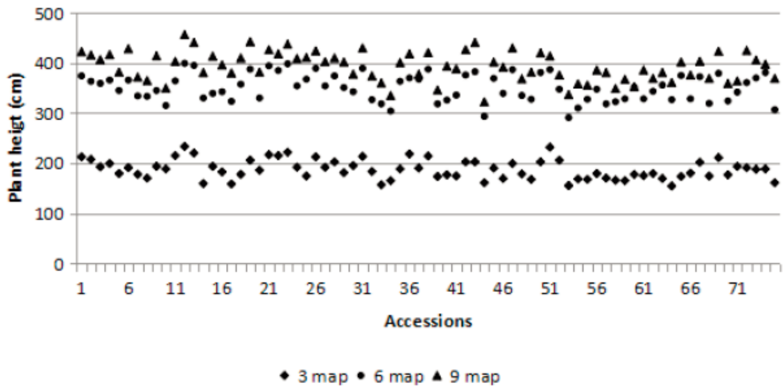


Figure 2. Plant height per accession at age 3, 6 and 9 MAP (Month After Planting) at Jambegede Research Station, planting season 2016.

root rot. Plants that thrived did not always have a good effect on tuber yields. The harvest index ranged from 0.11 to 0.63 (average 0.30) (Table 2). It showed that soil, management, and the environment are the important factors in crop production (where the important index is water availability and quality) (Oshunsanya and Nwosu 2018).

The number of tubers per plot ranged from 20 to 129 tubers (average of 60 tubers per plot), with yield per plot ranging from 4.98 kg to 34.52 kg (average of 14.66 kg per plot), or equivalent to 8.89 ton.ha^{-1} to 61.64 ton.ha^{-1} (average 26.11 ton.ha^{-1}). The order of all accessions from the highest to lowest tuber yield levels is presented in Figure 3. The rank of 10 accessions with the highest yield (20.50 kg per plot to 34.52 kg per plot equivalent to 36.61 ton.ha^{-1} to 61.64 ton.ha^{-1}) is respectively: MLG 10366, MLG 10365, MLG 10318 , MLG 10197, MLG 10325, MLG 10341, MLG 10018, MLG 10279, MLG 10298, and MLG 10263 (Table 2). Yield rank was quite wide and there were several accessions with high yields.

Characteristics of tuber morphology observed included tuber shape (Figure 4), texture of tuber epidermis (Figure 5), tuber epidermis color, and tuber cortex color (Figure 6). The frequency distribution of observations on these characters is presented in Table 3. Accession with the tuber shape of the conical cylindrical had 40 accessions, cylindrical 7 accessions, and irregular one accession, while the others had a mixture between conical and cylindrical (9 accessions), conical cylindrical and cylindrical (14 accession),

Table 2. Red mite attack scores, number of plants harvested, stover weight, and fresh tuber yield of top ten cassava accessions. Jambegede Research Station, Planting Season 2016

Registration number/ Accecion name	Red mite score	Number of plants harvested			Stover weight (kg per plant)	HI (%)	Number of tuber per plot	Tuber weight (kg per plot)	Tuber yield (ton.ha^{-1})	Tuber yield rank
		Normal	Fall down	Total						
MLG 10366	0.5	8.0	0.0	8.0	4.04	43.8	100	34.52	61.64	1
MLG 10365	1.0	8.0	0.0	8.0	4.03	62.7	83	33.82	60.39	2
MLG 10318	1.0	8.0	0.0	8.0	4.33	53.9	129	33.76	60.29	3
MLG 10197	0.5	8.0	0.0	8.0	3.71	45.3	82	26.57	47.45	4
MLG 10325	1.0	8.0	0.0	8.0	3.06	44.5	86	25.71	45.91	5
MLG 10341	0.5	8.0	0.0	8.0	2.67	46.5	88	22.58	40.32	6
MLG 10018	1.0	7.0	1.0	8.0	2.86	34.1	68	22.22	39.68	7
MLG 10279	1.0	8.0	0.0	8.0	2.74	42.0	80	20.92	37.36	8
MLG 10298	0.5	6.5	1.0	7.5	3.00	40.0	74	20.80	37.14	9
MLG 10263	1.0	6.5	1.5	8.0	3.22	41.7	54	20.50	36.61	10
Statistict of all accessions										
Minimum	0.5	0.0	0.0	4.0	4.7	10.5	20	4.98	8.89	
Maximum	1.5	8.0	8.0	8.0	13.2	62.7	129	34.52	61.64	
Average	0.8	4.9	2.2	7.7	8.7	29.9	60	14.62	26.11	

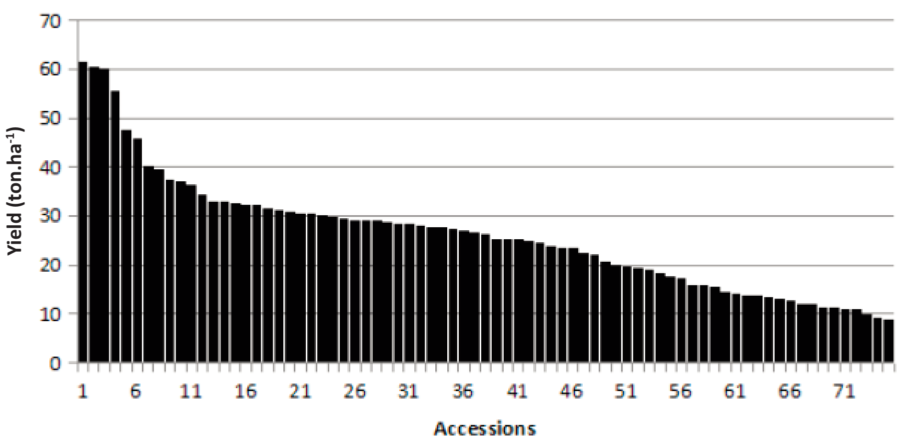


Figure 3. The registration number of cassava accession from highest to lowest tuber yield ranking at Jambegede research station, planting season 2016

Figure 4. Tuber shape categories in the characterization of cassava germplasms (1= conical; 2= conical-cylindrical; 3= cylindrical; 4= irregular).

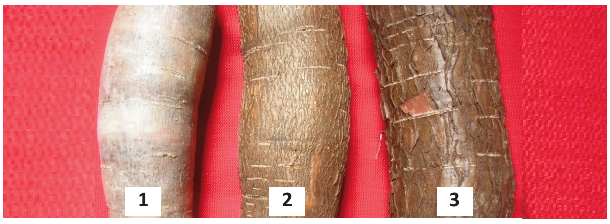


Figure 5. Texture of tuber epidermis (1= smooth; 2= intermediate ; 3= rough)

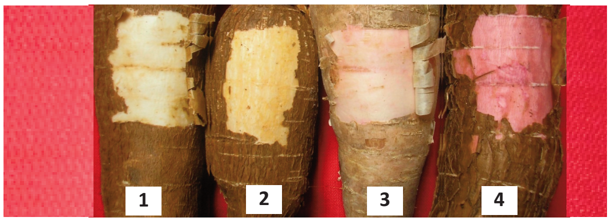


Figure 6. Colour of tuber cortex(1= White; 2= yellow; 3= pink; 4= purple or cream

Table 3. Morphological characteristics of fresh tuber from cassava accessions. Jambegede research station, Planting Season 2016

No	Characteristics	Categories and descriptions	Number of accessions
1	Tuber shape	1=conical	0
		2=conical cylindrical	40
		3=cylindrical	7
		4=irregular	1
		mixture 1 and 3	9
		mixture 2 and 3	14
		mixture 2 and 4	2
2	The texture of the outer skin surface	1=smooth	7
		2=medium	9
		3=rough	57
3	Outer colour of tuber surface	1=white or cream	7
		2=yellow	0
		3=light brown	5
		4=dark brown	61
4	Cortex Colour	1=white or cream	3
		2=yellow	46
		3=pink	15
		4=purple	9
5	Flesh/parenkhim colour	1=white or cream	42
		3=yellow	31
		4=orange	0
		5=pink	0

Remark: Character description refers to Fukuda et al. (2010).

conical cylindrical and irregular (two accessions). Tuber shape information was needed by the user because some processes of fresh tubers such as cassava chips, steamed cassava, fried cassava, and fermented cassava required a cylindrical tuber shape in order to obtain uniform shape and high yields of processed products. According to Yonis et al., (2020), cassava has various tuber morphologies and often has an irregular shape even though it is in the same genotype. This causes serious problems in harvesting and post-harvest processing.

Most accessions have tuber epidermis texture with a rough texture and dark brown color, while the tuber cortex color is yellow. Most of the accessions characterized have white or creamy tuber flesh (42 accessions), yellow one (31 accessions), while those that are orange and pink are missing. Cassava which has a yellow tuber color is very good for health because it contains pro vitamin A.

Characterization of steamed tubers was carried out on 70 accessions, because 5 (five) accessions were not observed due to insufficient tuber samples. The panelists' preference for steamed tubers includes aspects of color, texture, taste, and fiber. The frequency distribution of character observations is presented in Table 4. Most of the accessions characterized have broken steamed tubers, thick texture, not bitter (sweet), not fibrous, and the panelists liked it.

All accessions with high yield potential (10 accessions) have steamed tubers favored by panelists, even two accessions including MLG 10366 and MLG 10318 are very preferred because the tubers are broken, the texture is very good, it tastes sweet (not bitter taste), and it is not fibrous (Table 5). In addition, there are six other accessions whose steamed tubers are highly sought because their characteristics are almost the same as MLG 10366, but have low tuber yields. The accessions are: MLG 10221, MLG 10246, MLG 10390, MLG 10084, MLG 10242, and MLG 10334.

All accessions evaluated were initially selected to seek which tubers were not bitter. However, in this study there was one accession, namely MLG 10075 with bitter tubers. The accession had the lowest tuber yield, because since the age of 6 months the plants did not grow normally as the stems fell (out of a total of 8 plants only 2 plants had normal upright stems until harvest). The results of the correlation analysis showed that the number of fallen plants was negatively correlated with the tuber yield (r = -0.666 **, n = 75–2). High soil moisture

Table 4. Characteristics of steamed tuber in the evaluation of sweet cassava accessions

No	Characteristics	Descriptions	Number of accessions
1	Tuber broken level	1=not broken	3
		2=slightly broken	13
		3=broken	54
		4=very broken	5
2	Texture	1=tough	4
		2=slightly tender	3
		3=tender	57
		4=very tender	6
3	Taste	1=bitter	1
		2=rather btter	3
		3=sweet	66
4	Fiber	1=fibrous	3
		2=rather fibrous	6
		3=not fibrous	61
5	Levels of preference	1=don’t like	4
		2=rather like	6
		3=like	52
		4=realy like	8

Table 5. Starch content and organoleptic test of steamed tuber of top ten cassava accessions with high tuber yield. Jambegede research station, 2016 planting season

Registration number/ Accecion name	Starch content (%)	Dry matter content (%)	Tuber shape	Flesh colour	Tuber broken level	Texture	Taste	Fiber	Pref.	Rank
MLG 10366	22.0	39.3	2,3	White	3	4	3	3	4	1
MLG 10365	22.1	39.4	2,3	White	3	3	3	3	3	2
MLG 10318	17.7	33.3	2,3	White	3	4	3	3	4	3
MLG 10197	21.1	38.0	2	White	3	3	3	3	3	4
MLG 10325	21.7	38.9	2,3	White	3	3	3	3	3	5
MLG 10341	22.6	40.2	2	White	3	3	3	3	3	6
MLG 10018	20.9	37.7	3	White	3	3	3	3	3	7
MLG 10279	21.0	37.9	2	White	3	3	3	3	3	8
MLG 10298	21.3	38.3	2	White	3	3	3	3	3	9
MLG 10263	21.0	37.9	3	White	3	3	3	3	3	10
Statistics of all accessions										
Minimum	13.14	26.81								
Maximum	24.24	42.48								
Average	19.38	35.62								

Remarks: Tuber broken level: 1=not broken, 2=slightly broken, 3=broken, 4=very broken
Texture : 1=tough, 2=rather tender, 3=tender, 4=very tender
Taste : 1=bitter, 2=rather bitter, 3=not bitter
Fiber : 1=fibrous, 2=rather fibrous, 3=not fibrous
Preference : 1=don't like, 2= rather like, 3=like, 4=realy like

and long lasting effect on decreasing oxygen content, chemical and biological status of soil was not good for plant growth (Mullan and Barrett-Lennard, 2010).

Steamed tubers from MLG 10075 were not preferred because the bitter taste was also not chapped and the texture was tough even though the tubers were not fibrous. The results of simple correlation analysis showed that starch content was positively correlated with steaming tuber (r = 0.243 *, n = 70-2) and fiber content (r = 0.284 *, n = 70-2).

The prediction of starch content from the 15 accessions listed in Table 6 was carried out using the specific gravity method ranging from 13.1 % to 24.2 % (average 19.4 %) which was lower than the starch content of the analysis results in the laboratory using the Nelson Somogyi method (Marais et al, 1966). Likewise to the prediction of the level of dry matter, the results were 26.8 % – 42.5 % (average 35.6 %). However, this specific gravity method was still feasible to be used for the rapid selection of cassava clones with high levels of starch or dry ingredients, as it can be carried out on land easily, quickly and cheaply. The results of simple correlation analysis showed that the starch content was positively correlated with the tuber yield (r = 0.394 **, n = 75–2).

The results of physico-chemical properties analysis of fresh tubers including water content, HCN, starch, and amylose were carried out on 14 potentially high yield accessions representing non-bitter, good texture, non-fibrous taste of steamed tuber and one accession with bitter taste are presented in Table 6. HCN content ranged from 4.04 ppm to 15.24 ppm (average 9.40 ppm), water content 54.8 % to 64.2 % (average 59.5 %), starch content 23.7 % to 33.1 % (average 28.8 % wb), and amylose content ranged from 9.5 % to 12.5% (average 11.0 %). According to Ndubuisi and Chidiebere (2018), cassava is categorized as sweet (actually not bitter) if the HCN produced is about 20 mg of cyanide per kg of fresh root, while cassava is categorized bitter if it produces more than 50 times the HCN. Nevertheless, steamed tuber of the accession was used as a comparison (MLG 10075). The accession had bitter

Table 6. Physical and chemical properties of fresh tubers of sweet and bitter cassava accessions. Laboratory of. Food Chemistry, Balitkabi 2016

No	Clone /plot	Registration number/ accession name	Water content (%wb)	Water content (%db)	Dry matter content (%)	HCN content (ppm)	Starch content[1]		Amylosa content[2]	
							%wb	%db	%wb	%db
1	70	MLG 10366	58.38	4.63	44.81	5.39	30.98	73.90	12.08	28.82
2	69	MLG 10365	57.05	5.10	43.35	6.07	30.11	70.37	12.41	29.00
3	54	MLG 10318	61.47	4.55	40.90	4.04	27.65	71.61	10.63	27.53
4	33	MLG 10197	56.40	4.21	46.25	6.75	30.13	68.88	10.83	24.76
5	55	MLG 10325	59.99	4.43	43.36	11.47	29.29	73.26	10.17	25.44
6	58	MLG 10341	57.16	5.75	43.27	6.74	31.76	74.27	10.72	25.06
7	49	MLG 10298	59.15	4.22	41.04	8.09	29.53	72.10	11.77	28.73
8	43	MLG 10263	60.95	5.41	40.10	9.45	26.55	67.86	9.89	25.29
9	71	MLG 10367	61.64	4.68	39.53	15.24	26.35	68.72	10.17	26.54
10	41	MLG 10253	54.79	4.17	46.48	15.10	33.09	73.03	12.51	27.60
11	48	MLG 10295	63.39	4.42	40.67	5.40	24.54	66.86	9.97	27.16
12	76	MLG 10352	58.36	4.31	43.09	9.44	32.24	77.33	11.52	27.62
13	28	MLG 10138	64.24	4.63	38.13	10.80	23.68	66.25	9.45	26.45
14	74	MLG 10360	61.39	3.79	36.82	12.13	25.93	66.95	10.57	27.30
15	20	MLG 10075[*)]	74.78	5.28	28.58	82.88	15.75	62.60	5.52	21.94

Remark: [1)] Starch content= acid hydrolysis method was continued by sugar analysis using Nelson Somogyi method (Marais, 1966); [2)] Amylosa content= method from (Juliano, 1971); [*)] means bitter cassava accession

Figure 7. The performance of steamed tubers of 15 accessions analyzed for their physical and chemical properties

taste, unbroken shape, and bad texture, and relatively higher HCN content and water content, i.e 82.88 ppm and 74.8 %, while starch content and the amylose was relatively lower, which was 15.8 % and 5.5 %. The steamed tuber texture of the 15 accessions were presented in Figure 7.

The results of this study indicated that the assembly of cassava varieties required plant posture that was not too large so it would not collapse easily, because the level of plant collapse affects the yield. In addition, high starch content is also very important as it affects starch yield the quality of steamed tuber and fiber content.

CONCLUSIONS

There were 10 high yield potential accessions, with fresh tuber yield ranging from 36.61 $ton.ha^{-1}$ to 61.64 $on.ha^{-1}$. Physico-chemical analysis of fresh tubers on 15 accessions had average HCN level of 9.40 ppm, water content of 59.5 %, starch content of 28.8 % (wb), and amylose content of 11.0 % (wb). The bitter cassava had relatively higher levels of HCN and water content, i.e 82.88 ppm and 74.8 %, while the starch and amylose content were relatively lower, i.e 15.8 % (wb) and 5.5 % (wb).

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REFERENCES

Balai Penelitian Tanaman Aneka Kacang dan Umbi. (2017). *Kebun percobaan.* [online]. Available at: http://balitkabi.litbang.pertanian.go.id/profil/kebun-percobaan-2/. [Accessed 25 June 2020].

Chisenga, S.M., Workneh, T.S., Bultosa, G., and Laing, M. (2019). Proximate composition, cyanide contents, and particle size distribution of cassava flour from cassava varieties in Zambia. *AIMS Agriculture and Food*, 4(4), pp. 869–891.

Food and Agriculture Organization. (2013). *Cassava, a 21st century crop. In Save and grow: cassava, a guide to sustainable production intensification*. [Online]. Available at: http://www.fao.org/ag/save-and-grow/cassava/en/1/index.html [Accessed 25 June 2020].

Fukuda, W.M.G., Guevara, C.L., Kawuki, R., and Ferguson, M.E. (2010). *Selected morphological and agronomic descriptors for the characterization of cassava*. 1st ed., Ibadan: International Institute of Tropical Agriculture (IITA) Nigeria, pp. 19.

Hahn, S.K., Reynolds, L., and Egbunike, G.N. (1988). Cassava as livestock feed in Africa. *Proceedings of the IITA/ILCA/University of Ibadan workshop on the potential utilization of cassava as livestock feed in Africa*, pp. 159.

Indiati, S.W. (2012). Ketahanan varietas/klon ubikayu umur genjah terhadap tungau merah. *Jurnal Penelitian Pertanian Tanaman Pangan*, 31(1), pp. 53–59.

Juliano, B.O. (1971). A simplified assay for milled-rice amylose. *Cereal Science Today*, 16(10), pp. 334–340.

Laya, A., Koubala, B.B., Kouninki, H., and Nukenine, E.N. (2018). Effect of harvest period on the proximate composition and functional and sensory properties of gari produced from local and improved cassava (*Manihot esculenta*) varieties. *International Journal of Food Science*, 2018, pp. 1–15

Marais, J.P., de Wit, J.L., and Quicke, G.V. (1966). A critical examination of the Nelson-Somogyi method for the determination of reducing sugars. *Analytical Biochemistry*, 15(3), pp. 373–381.

Mullan, D.J. and Barrett-Lennard, E.G. (2010). Breeding crops for tolerance to salinity, waterlogging and inundation. In: M. P. Reynolds (Ed.), *Climate Change and Crop Production*. Wallingford, UK: CAB International, pp. 92–114.

Ndubuisi, N.D. and Chidiebere, A.C.U. (2018). Cyanide in cassava: A review. *International Journal of Genomics and Data Mining*, 2(1), pp. 1–10

Oshunsanya, O.S. and Nwosu, N.J. (2018). *Soil-water-crop relationship: A case study of cassava in the tropics*. Intech, tourism, 13. [online]. Available at: https://www.intechopen.com/books/advanced-biometric-technologies/liveness-detection-in-biometrics [Accessed 17 December 2020]

Sánchez, T., Dufour, D., Moreno, J.L., Pizarro, M., Aragón, I.J., Domínguez, M., and Ceballos, H. (2013). Changes in extended shelf life of cassava roots during storage in ambient conditions. *Postharvest Biology and Technology*, 86, pp. 520–528.

Teye, E., Asare, P., Amoah, R., and Tetteh, J. (2011). Determination of the dry matter content of cassava (*Manihot esculenta*, Crantz) tubers using specific gravity method. *APRN Journal of Agricultural and Biological Science*, 6(11), pp. 23–28.

Vieira, E.A., de Freitas Fialho, J., Faleiro, F.G., Bellon, G., da Fonseca, K. G., Carvalho, L.J. C.B., Silva, M.S., de Paula-Moraes, S.V., de Oliveira, C.M., and Denke, M.L. (2011). Characterization of sweet cassava accessions based on molecular, quantitative and qualitative data. *Crop Breeding and Applied Biotechnology*, 11(3), pp. 232–240.

Wyckhuys, K.A.G., Wongtiem, P., Rauf, A., Thancharoen, A., Heimpel, G.E., Le, N.T.T., Fanani, M.Z., Gurr, G.M., Lundgren, J.G., Burra, D.D., Palao, L.K., Hyman, G., Graziosi, I., Le, V.X., Cock, M.J.W., Tscharntke, T., Wratten, S.D., Nguyen, L.V., You, M., Lu, Y., Ketelaar, J.W., Georgen, G., and Neuenschwander, P. (2018). Continental-scale suppression of an invasive pest by a host-specific parasitoid underlines both environmental and economic benefits of arthropod biological control. *PeerJ*, 2018(10).

Yonis, B.O., Pino del Carpio, D., Wolfe, M., Jannink, J.L., Kulakow, P., and Rabbi, I. (2020). Improving root characterisation for genomic prediction in cassava. *Scientific Reports*, 10(1), pp. 1–12.