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Functional properties and cyanide content of starch and flour of selected cassava (Manihot esculenta crantz) mosaic disease (CMD) resistant varieties

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ABSTRACT
Flours and starches (<250μm) were produced from forty-four(44) Cassava Mosaic Disease (CMD) resistant varieties recently developed by the International Institute of Tropical Agriculture (IITA). Water and oil absorption capacity of the flour samples ranged from 1.050 to 1.350ml/g and1.350 to1.950ml/g, respectively. The loose and packed bulk densities of the flours were 0.3687 - 0.4961g/ml and 0.5357 – 0.7837g/ml, respectively. The swelling index of the flours was 1.247 - 1.460ml/g while the wettability was 17.00 - 40.00 seconds. Emulsion characteristic of the flours was 45.97 to 52.07%. Hydrogen cyanide (HCN) of the flours ranged from 2.10 to 7.87ppm. Flour pH ranged from 4.87 to 7.77. Water and oil absorption capacities of the starch samples ranged from 0.650 to 0.950ml/g and 1.100 to 1.450ml/g, respectively. Loose and packed bulk densities were 0.4842 - 0.5493g/ml and 0.6511 - 0.7465g/ml, respectively. Starch swelling index was 1.303 - 1.430ml/g while the wettability was 21.00 - 39.00 seconds. Emulsion characteristic of starch ranged from 41.03 to 49.00%. Hydrogen cyanide (HCN) content of the starch ranged from 1.40 to 3.20ppm while the pH ranged between 6.01and 8.39. The results of the functional properties and cyanide content of both flours and starches showed that there were significant differences among the cultivars. However, the cyanide content of the flours and starches from the CMD resistant cassava varieties are within the safe limit (<10ppm) and therefore safe for human consumption.

INTRODUCTION

Cassava is one of the most extensively cultivated tuber crops [1], which is widely consumed in the tropics [2,3]. It plays a food security role in Africa where annual production exceeds 80 million tones translating into an estimated 300 calories per day for more than 200 million people [4]. Cassava in the form of starch and flour is increasingly being used as a raw material for processing into a range of foods [5].

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Cassava flour can be used as a substitute to some extent for wheat flour in the confectionery and brewing industries [6].

The unique properties of cassava starch suggest its use for baby foods, non-allergen products and food for hospitalized persons [7]. Cassava has potential in the manufacture of various sweetners for the food industry [8]. The functional properties (water absorption capacity, oil absorption capacity, loose and packed bulk densities, swelling index, wettability, emulsion characteristics), will determine the potential of the flours and starches in food formulations.

The presence of cyanogenic glucoside in cassava and cassava products has been a concern in their utilization without detoxification as human food. The root of cassava is known to contain between 2-395mg of Linamrin/100kg of fresh root [9].

In addition to the perishable nature of harvested cassava roots, huge losses are incurred as a result of a disease known as Cassava Mosaic Disease (CMD)[10]. This situation has threatened the availability of cassava. Encouragingly, recent breeding research efforts have produced several CMD resistant cassava varieties, some of them yet to be released to farmers.

The objectives of this research work were:

1. To produce acceptable flour and starch from different CMD resistant varieties.
2. To determine the functional properties of flour and starch from the cultivars.
3. To evaluate the total cyanide content of the cassava products with a view to knowing the cultivars that fall within the FAO safe level.

MATERIALS AND METHODS

Fresh roots of 44 Cassava Mosaic Disease (CMD) resistant genotypes (TME 419, TMS 30752, TMS 4(2)1425, TMS 82/00058, M98/0028, M98/0040, M98/0068, 92B/00061, 92B/00068, 92/0057, 92/0067, 92/0325, 92/0326, 94/0026, 94/0039, 94/0561, 99/2123, 99/3073, 99/6012, 96/0523, 96/0603, 96/1317, 96/1565, 96/1569, 96/1632, 96/1642, 96/0002, 98/0505, 98/0510, 98/0581, 98/2101, 98/2226, 97/0162, 97/0211, 97/2205, 97/3200, 97/4763, 97/4769, 97/4779, 95/0166, 95/0289, 95/0379, NR8082,91/02324) were harvested manually from field plots at the National Root Crops Research Institute (NRCRI) Umudike, Abia State of Nigeria. Sample materials were 12 months old of the time of harvest.

Sample Preparation

In producing cassava flour, cassava roots were peeled, washed and grated with a field marshal (7.5HP diesel) engine. The grated pulp was bagged in sacks and tied. Each sack was mounted on a screw press and dewatered at the gari processing unit of the NRCRI, Umudike.The dewatered cake was broken into pieces with hand and then sun dried for 8 hours on a local mat and then further dried effectively in an electric hot air, thermo-regulated oven (Gallenkamp, BS model Ov-160) at a temperature of 60^0C for 8 hours. The dried material was milled in a single disc attrition mill (A446A model) and sieved with a 250µm mesh sieve. The flour obtained was packaged and sealed with an impulse sealer (Double leopard, SP-200H model) in cellophane bags and stored on a shelf at room temperature (23^0C) for further analysis.

For the cassava starch, the cassava roots were peeled, washed and mechanically grated as indicated above. The pulped mash was placed unto a muslin/ nylon screen, tied on clean bucket and the mash was sifted through the muslin screen by hand with the addition of water. The pulp was rinsed several times with clean tap water to extract enough starch. The filtrate was allowed to sediment for about three hours and the super- natant discarded. The sediment was washed twice before been thinly spread on nylon sheets and sun dried for six hours and then dried further in an electric hot air thermo-regulated oven at a temperature of 50^0C for 4 hours. The dried cake was milled using a single disc attrition mill

(A446A model) and sieved with a 250μm mesh sieve. The sieve – powdered starch obtained was packaged and sealed in cellophane bags and stored at room temperature (25^0C) for further analysis.

Analyses

The flour and starch samples were analyzed for water absorption capacity, oil absorption capacity, loose bulk density, wettabilty, packed bulk density, swelling index, emulsion characteristic, hydrogen cyanide (HCN) content and pH, respectively.

Water absorption capacity, oil absorption capacity, loose bulk density, packed bulk density, wettability and emulsion activity were determined according to Okezie and Bello [11]. Swelling index was determined according to the method described by Narayana and Narasinga [12]. pH was determined as specified by AOAC.[13]. The total hydrogen cyanide (HCN) content was determined according to the method described by Bradbury *et al* [14].

Data was analyzed according to the procedures of Steel and Torrie [15]. Determination of significant differences (P<0.05) between the varieties was by ANOVA, while Fishers Least Significant difference (LSD) was used for separating the means.

RESULTS AND DISCUSSIONS

Absorption Capacity.

Data on the water and oil absorption capacity of the flours and starches from the cassava cultivars are shown in Table 1. Water absorption capacity of the flour samples were found to be in the range of 1.050 to 1.35oml/g. Samples TME 419, 96/1565, 92/0067, TMS 82/00058 had the highest water absorption capacity while 96/1569 had the lowest. Oil absorption capacity of the flours ranged between 1.350 and 1.950ml/g. Flour sample TMS 4(2)1425 had the highest oil absorption capacity while variety 95/0379 and 99/3073 had the lowest. The starch samples had water absorption capacity of 0.659 to 0.950ml/g with variety 96/1565 and 98/2101 having the highest water absorption capacity while sample 97/3200 had the lowest. Oil absorption capacity of the starch ranged between 1.100 and 1.450ml/g. Varieties 91/02324, 96/1569, 95/0289 and 95/0166 had the highest oil absorption capacity while varieties 92/0067, 92/3200 and 95/0379 had the lowest. There was significant difference (P<0.05) in the absorption capacity of the flour and starch samples and also between the cultivars. Water absorption capacity is a useful indication of whether flours can be incorporated into aqueous food formulations, especially those involving dough handling [16]. Water absorption capacity is important in bulking and consistency of products as well as baking applications[17]. Thus, for water absorption capacity, TME 419, TMS82/00058, 92/0067, 96/1565 and 96/1565, 98/2101 for flour and starch respectively had the highest absorption capacity and are best accepted in baking applications.

Bulk Density

The loose and packed bulk densities of the flours and starches from the cassava cultivars are shown in Table 2. Loose bulk density of the flour samples was 0.3687 to 0.4961g/ml.

Sample 92/0069 had the highest loose bulk density among the cultivars while variety M98/0068 had the lowest. The flour samples had packed bulk density of 0.5357 to 0.7837g/ml with TMS 82/00058 having the highest packed bulk density and M98/0068 had the lowest. Loose bulk density of the starch samples ranged between 0.4842 and 0.5492g/ml. Variety 95/0166 had the highest loose bulk density while variety 92/0067 had the least. The starch samples had packed bulk density values of 0.6511 to 0.7465 g/ml with NR 8082 having the highest packed bulk density and variety 97/0162 the lowest. There was significant difference in ($P < 0.05$) in the bulk density of the flours and starches from the different cassava cultivars. Bulk density gives an indication of the greater ease of dispersability and reduction of paste thickness [18, 19]. Low bulk density of the starches is a good physical attribute when determining transportation and storability since the products can be easily carried and distributed to locations where they are required [20]. Low bulk density is advantageous for the infant food as both calorie and nutrient intake are enhanced per feed [21]. The low bulk density of the flours and starches (Table 2) would be an advantage in the preparations of complimentary food. High bulk density is a good physical attribute when determining mixing quality of particulate matter [22].

Swelling Index and Wettability

Values of the swelling index and wettability of the starch and flour samples are presented in Table 3. The flour samples had a swelling index of 1.247 to 1.460 ml/g with samples 95/0166 and 92B/00061 having the highest swelling index and M98/0028 had the lowest.

The values of the wettability of the flour samples ranged between 17.00 and 40.00. sec. with variety 97/0162 having the highest time of wettability and variety 95/0289 had the least time. The swelling index of the starch samples ranged between 1.303 and 1.430 ml/g with variety 97/4779 having the highest swelling index while M98/0026 had the least. The wettability of the starch samples ranged between 21.00 and 39.00 sec. Variety 98B/00061 had the highest time of wettability while variety 97/2205 had the least. The results in Table 3 show that there was significant variation ($P < 0.05$) in the swelling index and wettability of the flour and starch samples. Wettability is a function of the ease of dispersion/displacement of water by any sample. The sample with the lowest time of wettability would dissolve in water faster than samples with higher wettability. The flour and starch samples (Table 3) with the least time of wettability would perform better in textured and comminuted meat and baked products. High swelling capacity had been reported as part of the criteria for a good quality product [23].

Emulsion Characteristic

The emulsion characteristic of the flour and starch are shown in Table 4. The emulsion characteristic of the flour samples was 45.97 – 52.07%. Variety 96/1632 had the highest emulsion characteristic while variety 97/3200 had the lowest. The emulsion characteristic of the starch samples ranged between 41.03 and 49.00% with variety 92B/00068 having the highest emulsion characteristic and variety 96/0523 had the lowest. There was significant difference ($P<0.05$) in the emulsion characteristic of the flour and starch samples. High emulsion characteristic are an indication that the flour sample is an excellent emulsifier in various foods [24].

HCN Content and pH

The HCN content and pH of flours and starches from the different cultivars are presented in Table 5. The HCN content of the flour samples ranged between 2.10 and 7.87 ppm. Variety 96/1642 had the highest level of hydrogen cyanide while variety 92B/00068 had the lowest. The pH range of the flour samples was from 4.87 to 7.77 with variety 98/2101 having the highest pH value while variety 96/1642 had the lowest. For the starch samples, the HCN content ranged between 1.40 and 3.20 ppm. Variety 99/3073 had the highest level of HCN while variety 91/02324 had the lowest.

The pH values of the starch samples were between 6.01 and 8.39 with variety 97/4763 having the highest pH and NR8082 having the lowest. There was significant difference ($P<0.05$) in the HCN and pH of the flours and starches among the cultivars.

The World Health Organization (WHO) has set the safe level of cyanogens in cassava flour at 10 ppm [25]. The results of the HCN in Table 5 show that the products (flours and starches) are non-toxic since they fall within the FAO/WHO safe limit. pH is an important measurement of eating quality since it contributes to the taste of the food [26]. It also determines the type of micro-organisms the food product will tolerate.

CONCLUSION

It is well established that acceptable flours and starches could be produced from cassava for different types of food formulation. Moreover, the cyanide content of the cassava products fall within the safe limit of 10 ppm approved by the FAO/WHO. This safe level indicates that the products (flour and starch) could be used as substitute for wheat in baking industries as sources of energy and for other industrial applications. The cassava products have potential features with regard to functional properties and cyanide content.

Therefore it is suggested that more attention should be given to these cassava products (flours and starches) in the food industry.

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Table 1: **Absorption Capacity of Cassava Products**

Cultivars	Flour		Starch	
	Water (ml/g)	Oil (ml/g)	Water (ml/g)	Oil (ml/g)
TME 419	1.350^{A}	1.500^{EF}	0.850^{BC}	1.250^{CD}
TMS30572	1.150^{CD}	1.550^{E}	0.850^{BC}	1.250^{CD}
TMS 4(2)1425	1.250^{B}	1.950^{A}	0.750^{DE}	1.250^{CD}
TMS 82/00058	1.330^{A}	1.450^{F}	0.850^{BC}	1.150^{EF}
M98/0028	1.150^{CD}	1.650^{D}	0.750^{DE}	1.350^{B}
M98/0040	1.250^{B}	1.450^{F}	0.817^{CD}	1.250^{CD}
M98/0068	1.150^{CD}	1.450^{F}	0.850^{BC}	1.317^{BC}
92B/00061	1.150^{CD}	1.450^{F}	0.750^{DE}	1.150^{EF}
92B/00068	1.100^{DE}	1.450^{F}	0.750^{DE}	1.150^{EF}
92/0057	1.250^{B}	1.550^{B}	0.833^{BC}	1.350^{B}
92/0067	1.350^{A}	1.450^{F}	0.900^{AB}	1.100^{F}
92/0325	1.150^{CD}	1.500^{EF}	0.850^{BC}	1.150^{EF}
92/0326	1.150^{CD}	1.150^{E}	0.783^{CD}	1.350^{B}
94/0026	1.250^{B}	1.500^{EF}	0.750^{DE}	1.350^{B}
94/0039	1.150^{CD}	1.450^{F}	0.850^{BC}	1.350^{B}
94/0561	1.100^{DE}	1.650^{D}	0.750^{DE}	1.150^{EF}
99/2123	1.150^{CD}	1.150^{CD}	0.750^{DE}	1.217^{DE}
99/3073	1.150^{CD}	1.350^{G}	0.850^{BC}	1.200^{DE}
99/6012	1.150^{CD}	1.650^{D}	0.750^{DE}	1.150^{EF}
96/0523	1.250^{B}	1.550^{B}	0.750^{DE}	1.350^{B}
96/0603	1.183^{BC}	1.450^{F}	0.700^{EF}	1.350^{B}
96/1317	1.100^{DE}	1.550^{B}	0.750^{DE}	1.350^{B}
96/1565	1.350^{A}	1.750^{C}	0.950^{A}	1.250^{CD}
96/1569	1.050^{E}	1.550^{B}	0.800^{CD}	1.450^{A}
96/1632	1.250^{B}	1.550^{B}	0.750^{DE}	1.250^{CD}
96/1642	1.100^{DE}	1.550^{B}	0.850^{BC}	1.250^{CD}
98/0002	1.150^{CD}	1.550^{B}	0.850^{BC}	1.350^{B}
98/0505	1.100^{DE}	1.550^{B}	0.850^{BC}	1.250^{CD}
98/0510	1.150^{CD}	1.450^{F}	0.750^{DE}	1.150^{EF}
98/0581	1.250^{B}	1.550^{B}	0.850^{BC}	0.850^{BC}
98/2101	1.150^{CD}	1.550^{B}	0.950^{A}	1.250^{CD}
98/2226	1.150^{CD}	1.650^{D}	0.750^{DE}	1.350^{B}
97/0162	1.250^{B}	1.550^{B}	0.800^{CD}	1.250^{CD}
97/0211	1.100^{DE}	1.500^{EF}	0.850^{BC}	1.250^{CD}
97/2205	1.100^{DE}	1.550^{B}	0.700^{EF}	1.250^{CD}
97/3200	1.150^{CD}	1.550^{B}	0.650^{F}	1.100^{F}
97/4763	1.150^{CD}	1.750^{C}	0.750^{DE}	1.350^{B}
97/4769	1.150^{CD}	1.450^{F}	0.750^{DE}	1.250^{CD}
97/4779	1.150^{CD}	1.450^{F}	0.750^{DE}	1.250^{CD}
95/0166	1.150^{CD}	1.650^{D}	0.800^{CD}	1.450^{A}
95/0289	1.250^{B}	1.550^{B}	0.850^{BC}	1.450^{A}
95/0379	1.150^{CD}	1.350^{G}	0.750^{DE}	1.100^{F}
NR8082	1.250^{B}	1.850^{BC}	0.850^{BC}	1.250^{CD}
91/02324	1.150^{CD}	1.850^{BC}	0.850^{BC}	1.450^{A}

Mean of triplicate determinations.
Means with the same superscript within each column do not differ ($P>0.05$) significantly Means without the same superscript within each column differ ($P<0.05$) significantly

Table 2: **Bulk Densities of CMD Resistant Products**

Cultivars	Flour		Starch	
	Loose (g/ml)	**Packed(g/ml)**	**Loose (g/ml)**	**Packed (g/ml)**
TME 419	0.4127^{I}	0.6213^{PQ}	0.4969^{b}	0.7328^{D}
TMS30572	0.4251^{K}	0.6412^{N}	0.5027^{x}	1.7070^{U}
TMS 4(2)1425	0.4540^{B}	0.6644^{K}	0.4948^{c}	0.6697^{a}
TMS 82/00058	04941^{B}	0.7837^{A}	0.5217^{LM}	0.7081^{N}
M98/0028	0.305^{M}	0.5831^{Z}	0.5144^{p}	0.6736^{Z}
M98/0040	0.4069^{V}	0.6411^{N}	0.5339^{B}	0.6845^{T}
M98/0068	0.3687^{n}	0.5357^{e}	0.5211^{M}	0.7107^{M}
92B/00061	0.4921^{C}	0.7370^{C}	0.5053^{V}	0.7149^{K}
92B/00068	0.4601^{G}	0.6913^{G}	0.5096^{S}	0.7282^{F}
92/0325	0.3783^{J}	0.5846^{YZ}	0.5174^{o}	0.6753^{Y}
92/0326	0.4587^{H}	0.7157^{D}	0.5254^{H}	0.6772^{X}
94/0026	0.4005^{Y}	0.6409^{N}	0.5246^{I}	0.7422^{C}
94/0039	0.4006^{Y}	0.5858^{Y}	0.5298^{F}	0.6834^{U}
94/0561	0.3806^{i}	0.5769^{a}	0.5320^{D}	0.6946^{R}
99/2123	0.3991^{z}	0.6008^{U}	0.4884^{f}	0.6674^{b}
99/3073	0.3885^{f}	0.5705^{c}	0.5148^{P}	0.7059^{o}
99/6012	0.3736^{T}	0.5841^{Z}	0.5045^{W}	0.7307^{E}
96/0523	0.3976^{a}	0.6276^{O}	0.5002^{z}	0.6785^{W}
96/0603	0.4552^{J}	0.7372^{c}	0.5307^{E}	0.7115^{M}
96/1317	0.4415^{M}	0.6439^{M}	0.5111^{R}	0.7047^{P}
96/1565	0.4010^{x}	0.6277^{c}	0.4963^{b}	0.6793^{W}
96/1569	0.4586^{H}	0.6745^{I}	0.5299^{F}	0.7153^{K}
96/1632	0.3966^{b}	0.5723^{b}	0.5264^{G}	0.6925^{S}
96/1642	0.3959^{c}	0.6813^{H}	0.5267^{G}	0.6955^{R}
98/0002	0.4800^{E}	0.7079^{E}	0.4977^{a}	0.7173^{J}
98/0505	0.4282^{P}	0.6186^{R}	0.5121^{Q}	0.6805^{V}
98/0510	0.4286^{O}	0.6266^{O}	0.5187^{N}	0.7207^{H}
98/0581	0.4363^{N}	0.6827^{H}	0.5228^{J}	0.6651^{c}
98/2101	0.4041^{W}	0.5993^{U}	0.5117^{QR}	0.7103^{m}
98/2226	0.4566^{J}	0.6726^{J}	0.5328^{C}	0.7331^{O}
97/0162	0.3966^{b}	0.6201^{QR}	0.5075^{U}	0.6511^{F}
97/0211	0.4263^{Q}	0.6822^{H}	0.5083^{T}	0.7191^{I}
97/2205	0.4755^{F}	0.7003^{F}	0.5220^{KL}	0.6741^{z}
97/3200	0.3752^{e}	0.5831^{z}	0.4924^{d}	0.7011^{q}
97/4763	0.4204^{S}	0.5883^{W}	0.5242^{I}	0.7448^{B}
97/4769	0.3855^{h}	0.6188^{R}	0.5103^{S}	0.7002^{Q}
97/4779	0.3923^{d}	0.6155^{s}	0.5219^{KL}	0.6564^{e}
95/0166	0.3865^{a}	0.5864^{x}	0.5493^{A}	0.7124^{L}
95/0289	0.3894^{e}	0.6080^{T}	0.4976^{a}	0.6931^{S}
95/0379	0.4901^{D}	0.7435^{B}	0.5142^{P}	0.7063^{O}
NR8082	0.3968^{b}	0.6223^{P}	0.5224^{JK}	0.7465^{A}
91/02324	0.4121^{U}	0.5973^{V}	0.5016^{Y}	0.7241^{G}

Mean of triplicate determinations.
Means with the same superscript within each column do not differ (P>0.05) significantly Means without the same superscript within each column differ (P<0.05) significantly

Table 3: **Swelling Index and Wettability of Cassava Products**

Cultivars	Flour		Starch	
	Swelling Index	Wettability (Sec.)	Swelling Index	Wettability (Sec.)
TME 419	1.387^{D-G}	23.00^{N}	1.370^{E-J}	34.00^{E}
TMS30572	1.347^{I-M}	28.00^{IJ}	1.397^{B-F}	25.33^{N}
TMS 4(2)1425	1.360^{G-J}	27.00^{JK}	1.320^{K-M}	31.00^{FG}
TMS 82/00058	1.380^{D-H}	27.00^{JK}	1.400^{A-E}	32.00^{F}
M98/0028	1.247^{S}	25.00^{LM}	1.303^{M}	27.33^{K-M}
M98/0040	1.310^{N-P}	30.33^{FG}	1.357^{G-J}	26.33^{L-N}
M98/0068	1.373^{E-I}	29.00^{HI}	1.390^{C-F}	31.00^{FG}
92B/00061	1.457^{A}	20.33^{PQ}	1.423^{AB}	39.00^{FG}
92B/00068	1.330^{K-Q}	23.00^{N}	1.400^{A-E}	27.67^{J-L}
92/0057	1.397^{C-F}	21.67^{O}	1.353^{G-J}	36.33^{CD}
92/0067	1.313^{N-P}	20.33^{PQ}	1.320^{K-M}	28.33^{I-K}
92/0325	1.363^{DG-J}	21.33^{OP}	1.380^{D-H}	31.33^{FG}
92/0326	1.430^{C-E}	21.33^{OP}	1.313^{LM}	25.00^{N}
94/0026	1.330^{K-O}	23.67^{N}	1.417^{A-C}	38.33^{AB}
94/0039	1.277^{Q-S}	23.67^{N}	1.377^{E-H}	29.33^{HI}
94/0561	$1..293^{PQ}$	31.00^{EF}	1.367^{FI}	26.00^{MN}
99/2123	1.403^{C-E}	28.00^{IJ}	1.423^{AB}	34.33^{E}
99/3073	1.327^{L-O}	37.00^{C}	1.390^{C-F}	28.33^{I-J}
99/6012	1.260^{RS}	23.33^{RS}	1.370^{E-I}	28.00^{IJ}
96/0523	1.313^{N-P}	23.67^{N}	1.350^{H-K}	29.00^{H-J}
96/0603	1.403^{-E}	20.00^{Q}	1.350^{H-K}	25.67^{N}
96/1317	1.397^{C-F}	25.67^{L}	1.410^{A-D}	25.67^{N}
96/1565	1.403^{C-E}	24.00^{MN}	1.350^{H-K}	23.00^{I-J}
96/1569	1.390^{C-G}	30.67^{F}	1.423^{AB}	28.33^{I-J}
96/1632	1.367^{I-M}	20.33^{PQ}	1.383^{D-G}	38.00^{AB}
96/1642	1.360^{G-K}	29.00^{HI}	1.370^{E-I}	26.00^{MN}
98/0002	1.397^{C-F}	32.00^{DE}	1.320^{K-M}	21.00^{P}
98/0505	1.400^{C-F}	38.33^{B}	1.423^{AB}	31.33^{FG}
98/0510	1.347^{I-M}	25.67^{L}	1.320^{K-M}	26.00^{MN}
98/0581	1.370^{F-J}	26.00^{KL}	1.390^{C-F}	26.00^{MN}
98/2101	1.290^{P-R}	23.33^{N}	1.390^{C-F}	31.00^{FG}
98/2226	1.320^{M-P}	23.00^{N}	1.340^{I-L}	26.00^{MN}
97/0162	1.420^{BC}	40.00^{A}	1.410^{A-D}	31.00^{BC}
97/0211	1.360^{G-K}	26.00^{KL}	1.340^{I-L}	30.33^{GH}
97/2205	1.350^{H-M}	23.33^{N}	1.420^{A-C}	21.00^{P}
97/3200	1.340^{J-N}	26.00^{KL}	1.380^{D-H}	25.00^{N}
97/4763	1.350^{H-M}	20.00^{Q}	1.420^{A-C}	36.00^{CD}
97/4769	1.300^{O-Q}	28.33^{HI}	1.340^{I-L}	31.00^{FG}
97/4779	1.450^{AB}	27.00^{JK}	1.430^{A}	35.00^{DE}
95/0166	1.460^{A}	30.67^{F}	1.330^{J-M}	29.33^{HI}
95/0289	1.400^{C-F}	17.00^{R}	1.350^{H-K}	29.33^{HI}
95/0379	1.410^{CD}	29.33^{GH}	1.390^{C-F}	32.00^{F}
NR8082	1.450^{AB}	29.33^{GH}	1.420^{A-C}	32.00^{F}
91/02324	1.353^{H-L}	33.00^{D}	1.390^{C-F}	23.00^{I-J}

Mean of triplicate determinations.
Means with the same superscript within each column do not differ ($P>0.05$) significantly
Means without the same superscript within each column differ ($P<0.05$) significantly

Table 4 : **Emulsion Characteristic of Cassava Products**

Cultivars	Flour Emulsion Activity (%)	Starch Emulsion Activity (%)
TME 419	49.43^{LM}	45.80^{J-O}
TMS 30572	47.63^{Q}	48.00^{B}
TMS 4(2)1425	50.87^{D-F}	45.93^{I-M}
TMS 82/00058	48.50^{OP}	45.40^{O-R}
M98/0028	51.73^{AB}	45.47^{N-Q}
M98/0040	47.33^{QR}	46.97^{EF}
M98/0068	50.33^{G-I}	47.40^{C-E}
92B/00061	48.27^{P}	46.13^{H-K}
92B/00068	51.20^{CD}	49.00^{A}
92/0057	50.43^{F-I}	46.23^{H-J}
92/0067	51.77^{AB}	47.43^{CD}
92/0325	50.13^{J-K}	47.33^{DE}
92/0326	47.53^{Q}	46.00^{I-L}
94/0026	49.30^{MN}	44.83^{S-V}
94/0039	51.87^{AB}	45.23^{P-S}
94/0561	48.30^{P}	46.50^{GH}
99/2123	48.90^{NO}	46.83^{FG}
99/3073	46.17^{S}	44.93^{S-V}
99/6012	51.13^{D}	44.70^{TV}
96/0523	49.77^{JK}	41.03^{X}
96/0603	50.03^{I-K}	45.00^{R-U}
96/1317	50.03^{I-K}	45.00^{R-U}
96/1565	49.50^{LM}	44.53^{V}
96/1569	50.27^{G-I}	46.33^{HI}
96/1632	52.07^{A}	48.10^{B}
96/1642	50.67^{E-G}	47.83^{BC}
98/0002	46.90^{R}	44.57^{UV}
98/0505	48.53^{OP}	46.00^{I-L}
98/0510	47.57^{Q}	45.20^{QS}
98/0581	51.03^{DE}	46.83^{FG}
98/2101	50.00^{I-J}	45.20^{Q-S}
98/2226	50.03^{I-J}	45.50^{M-Q}
97/0162	48.90^{NO}	45.73^{K-O}
97/0211	49.77^{J-L}	45.70^{K-O}
97/2205	48.70^{OP}	45.67^{L-P}
97/3200	45.97^{S}	45.87^{J-N}
97/4763	51.60^{BC}	45.97^{I-L}
97/4769	50.60^{E-H}	46.20^{H-J}
97/4779	49.50^{LM}	45.10^{Q-T}
95/0166	51.23^{CD}	44.73^{I-V}
95/0289	50.20^{H-J}	47.13^{D-F}
95/0379	49.73^{K-M}	44.57^{UV}
NR8082	51.70^{AB}	47.23^{D-F}
91/02324	50.40^{G-I}	44.67^{T-V}

Mean of triplicate determinations.

Means with the same superscript within each column do not differ (P>0.05) significantly Means without the same superscript within each column differ (P<0.05) significantly

Table 5: **Hydrogen Cyanide (HCN) Content and pH of Cassava Products**

Cultivars	Flour		Starch	
	HCN (ppm)	pH	HCN (ppm)	pH
TME 419	5.80^{G}	6.03^{V}	2.30^{F-H}	$8.15B^{C}$
TMS30572	5.50^{H}	6.64^{R}	2.17^{I-J}	8.07^{CD}
TMS 4(2)1425	4.10^{UV}	7.42^{F}	2.17^{I-J}	7.41^{F-H}
TMS 82/00058	7.33^{C}	7.22^{HI}	2.17^{I-J}	7.31^{G-J}
M98/0028	5.50^{H}	7.75^{D}	2.57^{D}	7.42^{F-H}
M98/0040	5.30^{IJ}	7.03^{L}	2.30^{F-H}	8.04^{C-E}
M98/0068	4.33^{R-T}	7.08^{K}	3.17^{A}	7.21^{I-L}
92B/00061	5.20^{J-T}	7.13^{J}	2.33^{FG}	7.88^{DE}
92B/00068	2.10^{a}	6.25^{S}	2.17^{I-K}	7.12^{J-L}
92/0057	5.30^{IJ}	6.17^{T}	2.40^{EF}	8.15^{bc}
92/0067	6.30^{F}	7.02^{L}	2.30^{F-H}	6.87^{M}
92/0325	3.53^{x}	7.67^{B}	2.17^{JK}	7.87^{DE}
92/0326	4.10^{UV}	7.07^{K}	2.07^{K-M}	8.12^{BC}
94/0026	3.50^{X}	7.03^{L}	2.00^{LM}	8.20^{A-C}
94/0039	5.10^{K-M}	7.13^{J}	1.80^{OP}	8.27^{AB}
94/0561	4.10^{UV}	7.21^{I}	2.07^{K-M}	7.12^{J-L}
99/2123	4.40^{RS}	7.47^{E}	2.03^{L}	7.06^{K-M}
99/3073	4.30^{ST}	7.02^{L}	3.20^{A}	7.25^{F}
99/6012	4.60^{PQ}	6.86^{N}	2.30^{F-H}	6.62^{N}
96/0523	4.00^{V}	7.21^{I}	3.00^{B}	7.15J-^{L}
96/0603	3.00^{Z}	6.64^{O}	2.17^{I-K}	7.20^{J-L}
96/1317	7.57^{B}	6.50^{Q}	3.30^{B}	7.24^{H-K}
96/1565	3.30^{Y}	7.43^{F}	2.30^{F-H}	7.85^{E}
96/1569	4.50^{QR}	7.24^{H}	3.00^{B}	6.53^{N}
96/1632	5.27^{JK}	7.33^{G}	2.20^{H-J}	6.87^{M}
96/1642	7.87^{A}	4.87^{X}	1.77^{P}	8.12^{BC}
98/0002	3.80^{W}	7.62^{C}	2.07^{K-M}	7.40^{F-I}
98/0505	3.40^{XY}	7.43^{F}	1.70^{P}	7.87^{E}
98/0510	4.80^{NO}	7.07^{K}	2.10^{J-L}	7.51^{E}
98/0581	4.70^{OP}	6.63^{O}	2.47^{DE}	6.67^{N}
98/2101	4.70^{OP}	7.73^{A}	2.30^{F-H}	8.10^{BC}
98/2226	4.80^{NO}	6.45^{R}	2.93^{B}	6.46^{N}
97/0162	4.93^{MN}	6.87^{N}	2.07^{K-M}	7.30^{H-J}
97/0211	4.10^{UV}	6.60^{P}	1.90^{NO}	6.58^{N}
97/2205	7.50^{A}	7.60^{C}	2.23^{G-I}	8.14^{BC}
97/3200	4.20^{TU}	7.30^{G}	2.23^{G-I}	8.03^{C-E}
97/4763	3.30^{Y}	7.03^{L}	1.97^{MN}	8.39^{A}
97/4769	4.80^{NO}	6.07^{U}	2.07^{K-M}	6.50^{N}
97/4779	5.10^{K-M}	5.00^{W}	2.23^{G-I}	6.61^{N}
95/0166	5.47^{K-M}	7.42^{F}	2.80^{C}	7.55^{F}
95/0289	6.50^{E}	6.97^{M}	2.40^{EF}	7.88^{DE}
95/0379	6.83^{D}	7.03^{L}	2.23^{G-I}	7.42^{F-H}
NR8082	5.30^{J-L}	5.02^{W}	1.47^{Q}	6.01^{O}
91/02324	5.03^{LM}	6.03^{V}	1.40^{Q}	7.01^{LM}

Mean of triplicate determinations.
Means with the same superscript within each column do not differ (P>0.05) significantly Means without the same superscript within each column differ (P<0.05) significantly

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