Effects of fermentation length and varieties on the pasting properties of sour cassava starch

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Abstract

The effects of length of fermentation (5, 10, 15, 20 and 25 days) on pasting properties of sour starches produced from six cassava varieties were investigated. There were significant differences ($p < 0.05$) in pasting properties except pasting temperature and breakdown irrespective of the days of fermentation. Peak viscosity ranged from 308.50 to 466.63 RVA, trough ranged from 67.25 to 198.75 RVA, break down ranged from 147.71 to 320.25 RVA, final viscosity ranged from 100.29 to 233.00 RVA, set back ranged from 31.59 to 54.58 RVA, peak time ranged from 3.60 min to 4.06 min and pasting temperature ranged from 62.85 to 65.45 °C. Sour starches made from cassava TMS 30572, TMS 4(2) 1425 and 96/0603 recording the highest values. Sour cassava starch is used for making typical bread-like products such as "paodequeijo" in Brazil and "pandeyuca" in Colombia.

Keywords: Cassava, fermentation, pasting, starch, varieties,

Introduction

Cassava root is normally processed before consumption as a means of detoxification, preservation and modification and various fermented cassava products are available including 'gari', 'fufu' and 'lafun' (Oyewole, 1991). Fermentation processes play important roles in food technology in developing countries. In traditional fermentation processes, natural micro-organisms are employed in the preparation and preservation of different types of food. These processes add to the nutritive value of foods as well as enhancing flavour and other desirable qualities associated with digestibility and edibility. The fermentation techniques are often characterized by the use of simple, non-sterile equipment, chance or natural inoculums, unregulated conditions, sensory fluctuations, poor durability, and unattractive packaging of the processed products (Nout, 1985). Fermentation is the metabolic process in which carbohydrates and compounds are oxidized with the release of energy in the absence of any external electron acceptors. This is a molecular characterization and the word "fermentation" has had many shades of meaning in the past (Prescott and Dunn, 1957; Doelle, 1975). Many African foods are fermented before consumption and the lactic acid bacteria are widely used as starter organisms in these food fermentations because they convert sugars into organic acids thus improving the organoleptic and rheological properties of the products (Vogel *et al,* 2002). This paper studies the effects of fermentation period on pasting properties of sour cassava starch.

Materials and Methods

Materials: Fresh cassava roots of 3 CMD resistance clones (96/0603, 96B/00061, 96/01632) and 3 newly released cassava (4(2)1425, 30572, TME 1) from IITA trial field were used. The cassava plants were about 10-12 months old at the time of harvest. The cassava roots were processed within 60 minutes after harvesting.

Starch extraction: The traditional Eastern Nigerian methods (Osunsami *et al*, 1989; Oyewole and Obieze, 1995) were used. Cassava roots (50kg) were peeled, washed in water and grated with a commercial mechanical grater. The resultant pulp was immediately sieved through a screen and suspended in 70L of waters. This separates the fibrous and other coarse root material from the starch pulp (Oyewole and Odunfa, 1989; Oyewole and Obieze, 1995). The starch pulp was allowed to settle for 4-6hrs before decanting. The thick starch cake at the bottom of the bowl was pressed to remove water.

Sour starch production: Sour cassava starch was produced following Brabet *et al* (1998) method with little modification. Sour dough was produced by mixing 200g native starch and 200 ml of distilled water and fermented at room temperature (35 ± 2°C). This involved natural fermentation of cassava starch for 5, 10, 15, 20, and 25 days

followed by oven (Fisher Scientific Isotemp Oven, model 655F, Chicago, USA) drying at 50°C to between 10-12% moisture content. The dried sample was milled and stored in a cool place for analysis.

Determination of pasting properties: Pasting properties of starches were measured by using a Rapid Visco Analyser (RVA) (Newport Scientific Instruments, Warriewood, Australia, following the RVA corn starch method (AACC, 2000). Sour cassava starch (3.0g, db), was suspended in distilled water (25ml), and the suspension was thoroughly stirred in the RVA at 960rpm for 10sec and then at 160rpm for the remainder of the test. The temperature was first maintained at 50 °C for 1min for equilibration and then raised to 95 °C at 12 °C/min. The sample was kept at 95 °C for 2.4min, cooled to 50 °C at 12 °C/min and finally maintained at 50 °C for 2 min. The experiments were conducted in duplicate and the average values were recorded. The parameters recorded were pasting temperature (P temp), peak viscosity (PV), peak time (P time), trough, breakdown, set back and final viscosity.

Statistical analysis: Data generated from all experiments were subjected to Analysis of variance and means were separated by Duncan's Multiple Range Test using Statistical Analysis Software (SAS), (Model 8e,SAS institute Inc. Cary, NC, USA).

Results

Pasting properties of sour starch at different length of fermentation.

Table 1-5 shows the pasting properties of sour starch at different length of fermentation, for 5 days fermented starch, peak viscosity during heating was found to be between 308.50 RVU for 96/01632 to 466.63 RVU for 30572, trough ranged from 109.79 RVU for 96/01632 to 194.63 RVU for 4(2) 1425, breakdown ranged from 194.83 RVU for 96/01632 to 320.25 RVU for 30572, final viscosity ranged from 144.50 RVU for 96/01632 to 199.71 RVU for 30572, setback ranged from 34.71 RVU for 96/01632 to 44. 08 RVU for 30572, peak time ranged from 3.80 min for 4(2) 1425 to 3.96 min for 96.0603 and pasting temperature ranged from 63.10 °C for 30572 to 64.13 °C for TME1 (Table 1). Significant differences ($p<0.05$) were observed in peak viscosity, breakdown, final viscosity, set back and pasting temperature while no significant differences were observed in trough and peak time.

For 10 days sour starch, peak viscosity values ranged from 352.08 RVU for 96/01632 to 446.54 RVU for 96/0603, trough ranged from 113.21 RVU for 92B/00061 to 283.33 RVU for 96/0603, breakdown ranged from 208.34 RVU for 4(2) 1425 to 200.42 RVU for 96/0603, final viscosity ranged from 153.92 RVU for 92B/00061 to 199.71 RVU for 30572, setback ranged from 35.15 RVU for 4(2) 1425 to 47.58 RVU for 96/0603, peak time ranged from 3.78 min for 4(2) 1425 to 4.06 min for 96/0603 and pasting temperature ranged from 62.85 °C for 96/0603 to 64.08 °C for 92B/00061 (Table 2).There were no significant differences in peak viscosity, breakdown, setback, peak time and pasting temperature while significant differences were observed in trough and final viscosity at 5 % level.

For 15 days sour starch, peak viscosity values ranged from 333.25 RVU for 96/01632 to 440.33 RVU for 30572, trough ranged from 110.05 RVU for 926/01632 to 145.42 RVU for 96/0603, breakdown ranged from 199.17 RVU for 96/01632 to 293.42 RVU for 30572, final viscosity ranged from 147.25 RVU for 92B/00061 to 189.290 RVU for 96/0603, setback ranged from 31.59 RVU for 92B/00061 to 53.63 RVU for 4(2)1425, peak time ranged from 3.72 min for 4(2) 1425 to 4.04 min for 92B/00061 and pasting temperature ranged from 63.00 °C for 92B/00061 to 65.075 °C for TME1 (Table 3).There were significant differences in peak viscosity, breakdown, setback, peak time, trough, and final viscosity at $p<0.01$ level while no significant differences was observed in pasting temperature.

For 20 days sour starch, peak viscosity values ranged from 290.29 RVU for 96/01632 to 410.84 RVU for 4(2) 1425, trough ranged from 67.25 RVU for 92B/00061 to 198.75 RVU for 4(2) 1425, breakdown ranged from 147.71 RVU for 96/01632 to 229.50 RVU for 92B/00061, final viscosity ranged from 100.29 RVU for 92B/00061 to 233.00 RVU for 4(2) 1425, setback ranged from 33.04 RVU for 92B/00061 to 54.58 RVU for 30572, peak time ranged from 3.60min for 92B/00061 to 3.78 min for 96/0603 and pasting temperature ranged from 64.25 °C for 4(2)1425 to 65.45°C for 30572 (Table 4).There were significant differences in peak viscosity, breakdown, setback, peak time,

trough and final viscosity while no significant differences was observed in pasting temperature. For 25 days sour starch, peak viscosity values ranged from 333.17 RVU for 4(2)1425 to 380.75 RVU for TME 1, trough ranged from 98.79 RVU for 4(2)1425 to 134.17 RVU for 30572, breakdown ranged from 201.295 RVU for 4(2)1425 to 228.96 RVU for TME1, final viscosity ranged from 140.33 RVU for 4(2)1425 to 167.75RVU for 30572, setback ranged from 33.58 RVU for 30572 to 41.54 RVU for 4(2)1425, peak time ranged from 3.60 min for 4(2)1425 to 3.90 min for 92B/00061 and pasting temperature ranged from 63.76 °C for 92B/00061 to 65.13 °C for 30572 (Table 5).There were significant differences in peak viscosity, setback, peak time, trough and final viscosity at 5% confidence level while no significant differences were observed in pasting temperature and breakdown.

Discussion

During the spontaneous fermentation, pH fell gradually from 6.00 at mixing to 3.91 at the end of fermentation (25 days). As the pH decreases, the TTA increase indicating that the starch is becoming more acidic in nature (Fig 1). There were changes in leavening and temperature with time. Fermenting the roots resulted in a decrease in soluble sugars, cyanide content, and pH of starches. This is in agreement with Ezeala (1984) and Numfor (1995). Several workers have reported similar trend in cereal-based fermentation (Hounhouigan *et al*, 1993) and root based fermentation (Oyewole 1990; Brabet *et al* 1998). The pH of the non-fermented cassava starch is usually 6-7 (Brabet, 1994). It decreased to 4- 4.5 after sedimentation and reached 3-4 at the end of the fermentation (Fig 2). This pH shift was correlated with the increasing of the TTA due to the production of organic acids, mainly lactic acid and substantial amount of acetic acid. These results confirm that the lactic acid bacteria are the predominant fermentative micro-flora.

Pasting temperature gives an indication of the gelatinization time during processing. It is the temperature at which the first detectable viscosity is measured and an index characterized by initial change due to the swelling of starch. Pasting temperature has been reported to relate to water binding capacity, a higher pasting temperature implies higher water binding capacity, higher gelatinization and lower swelling property of starch due to high degree of association between starch granules (Oyewole, 1990).

The transition from a suspension of starch granules to a paste, when heat is applied, is accompanied by a large increase in viscosity, changes in viscosity also accompany the formation of gels upon cooling of starch pastes. Similar pasting temperature for cassava starch has also been reported by Dreher and Berry (1983) 62 °C and Dreher et al. (1983) 67 °C. During the hold period of a typical pasting test, the sample is subjected to a period of constant temperature (usually 95 °C) and mechanical shear stress. This further disrupts the starch granule and amylose molecules generally leach out into solution and align in the direction of the shear. A gradual decrease of the paste viscosity during the hold period indicates thermal breakdown of starch and thus, may be considered as a measure of stability. The period is sometimes called shear thinning, holding strength, hot paste viscosity or trough due to the accompanied breakdown in viscosity. It is the minimum viscosity value in the constant temperature phase of RVA profile and measures the ability of paste to withstand breakdown during cooling. Large values indicate little breakdown of sample starches. The rate of breakdown depends on the nature of the material, the temperature and degree of mixing and shear applied to the mixture (IITA, 2001).

As the temperature is increased, the starch granules swell and increase the viscosity of the starch paste until the peak viscosity is reached. A higher peak viscosity corresponds with a higher thickening power of a starch. A fall in peak viscosity and viscosity breakdown was observed for fermented samples, while the pasting temperature was enhanced significantly (Alummoottil et al, 2004).

Conclusion

The study has shown that varieties have significant effect on the qualities of starch especially in pasting properties. Fermentation has significant effect on the pasting properties of sour cassava starch. During the fermentation process there is not only an acid modification, but also an enzymatic attack, giving to the sour starch certain properties which in turn produce a baked product with typical and acceptable characteristics. Sour cassava starch is used for making typical bread-like products such as “paodequeijo” in Brazil and “pandeyuca” in Colombia. The wide variations in the properties of the starches from the different cassava varieties imply that the starches have potentials for a wide range of products.

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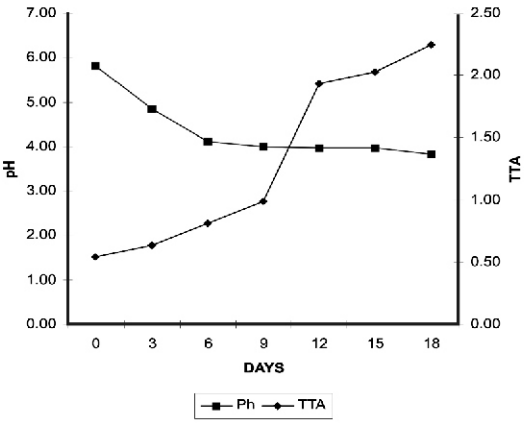

Fig 1:Fermentation effect on cassava starch for 20 days

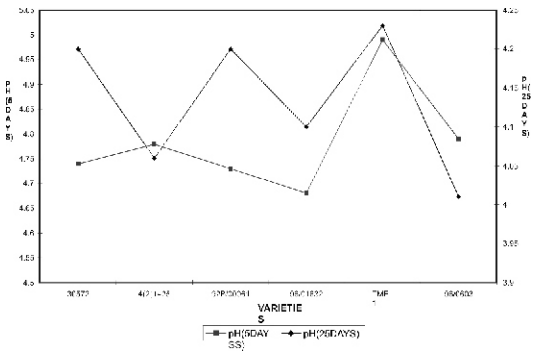

Fig 2: pH comparison before and after fermentation

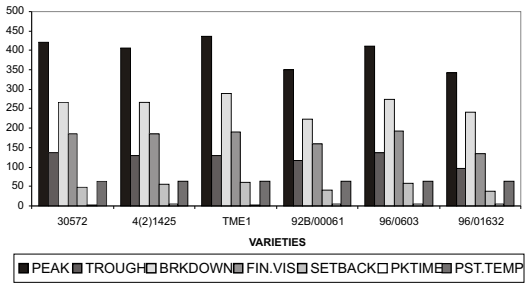

Figure 3: Varietal effect on pasting properties of sour starch

Table 1: Pasting properties of fermented starch for 5days length of fermentation.

Varieties	Peak Viscosity (RVU)	Trough (RVU)	Break Down (RVU)	Final Viscosity (RVU)	Set Back (RVU)	Peak Time (Minutes)	Pasting Tempe-rature (^{o}C)
30572	466.63a	155.63a	320.25a	199.71a	44.08a	3.88a	63.10c
4(2)1425	460.09a	194.63a	224.80c	192.83ab	34.71c	3.80a	64.13a
92B/00061	357.25c	114.71a	235.42bc	153.09c	38.38bc	3.90a	63.73ab
96/01632	308.50d	109.79a	194.83d	144.50c	34.71c	3.93a	63.38ab
96/0603	395.75b	139.96a	255.33b	182.67b	42.71ab	3.96a	63.45bc
TME1	458.36a	194.58a	222.26c	192.41ab	36.20c	3.83a	64.13a
Mean	407.76	151.55	242.15	177.53	38.46	3.88	63.65
R-Square	0.99	0.76	0.98	0.97	0.92	0.70	0.91
C.V	2.858	21.65	4.07	3.23	5.42	1.54	0.314
Std Dev	63.49	45.34	41.88	23.56	5.12	0.07	0.45
Range	308.50-466.63	109.79-194.63	194.83-320.25	144.50-199.71	34.71-42.71	3.80-3.96	63.10-64.13
P of Clone	**	NS	**	**	*	NS	*

Each value represent mean of three replicates.

Mean values having the same superscript within column are not significantly different at 5% confidence level.

*P<0.05

** P<0.01; *** P<0.0001; NS Not Significant

Table 2: Pasting properties of fermented starch for 10days length of fermentation.

Varieties	Peak Viscosity (RVU)	Trough (RVU)	Break Down (RVU)	Final Viscosity (RVU)	Set Back (RVU)	Peak Time (Min)	Pasting Tempe-rature (^{o}C)
30572	370.63b	133.13b	230.33bc	167.08bc	33.96a	3.88ab	63.23ab
4(2)1425	364.34b	130.50bc	208.34c	175.50b	35.15a	3.78b	63.10ab
92B/00061	353.50b	113.21d	235.04abc	153.92c	40.71a	3.99ab	64.08a
96/01632	352.08b	121.96c	215.29bc	160.34bc	38.38a	3.81b	63.80ab
96/0603	446.54a	152.84a	283.33a	200.42a	47.58a	4.06a	62.85b
TME1	402.80ab	133.09b	262.21ab	174.21b	41.13a	3.88ab	63.93a
Mean	381.65	130.79	239.09	171.91	39.48	3.88	63.50
R-Square	0.78	0.97	0.82	0.91	0.53	0.78	0.79
C.V	7.30	2.58	8.07	4.19	17.26	1.94	0.59
Std Dev	40.44	13.17	30.84	16.37	6.70	0.11	0.55
Range	352.08-446.54	113.21-152.84	208.34-235.04	153.92-200.42	33.96-47.58	3.78-4.06	62.85-64.08
P of Clone	NS	**	NS	*	NS	NS	NS

Each value represent mean of three replicates.

Mean values having the same superscript within column are not significantly different at 5% confidence level.

*P<0.05

** P<0.01; *** P<0.0001; NS Not Significant

Table 3: Pasting properties of fermented starch for 15days length of fermentation.

Varieties	Peak Viscosity (RVU)	Trough (RVU)	Break Down (RVU)	Final Viscosity (RVU)	Set Back (RVU)	Peak Time (Min)	Pasting Tempe-rature (^{o}C)
30572	440.33a	135.58ab	293.42a	184.84a	49.25b	3.85ab	63.53ab
4(2)1425	406.50b	134.59b	243.04b	188.21a	53.63a	3.72b	63.98ab
92B/00061	347.84c	115.67c	231.55b	147.25c	31.59d	4.04a	63.00b
96/01632	333.25c	110.05c	199.17c	151.13c	41.08c	3.73b	64.55ab
96/0603	388.92b	145.42a	241.46b	189.29a	43.88c	3.98a	64.50ab
TME1	414.54ab	140.75ab	246.38b	173.25b	32.50d	3.70b	65.08a
Mean	388.56	130.34	242.50	172.33	41.99	3.83	64.10
R-Square	0.96	0.97	0.95	0.99	0.99	0.89	0.68
C.V	2.88	2.94	4.15	1.81	2.63	1.95	1.17
Std Dev	39.85	13.79	29.73	18.16	8.60	0.15	0.89
Range	333.25-440.33	110.05-145.42	199.17-293.42	147.25-189.29	31.59-53.63	3.70-4.04	63.00-65.08
P of Clone	**	**	**	**	***	*	NS

Each value represent mean of three replicates.

Mean values having the same superscript within column are not significantly different at 5% confidence level.

*P<0.05

** P<0.01

*** P<0.0001; NS Not Significant

Table 4: Pasting properties of fermented starch for 20days length of fermentation.

Varieties	Peak Viscosity (RVU)	Trough (RVU)	Break Down (RVU)	Final Viscosity (RVU)	Set Back (RVU)	Peak Time (Min)	Pasting Tempe-rature (^{o}C)
30572	400.67a	157.00ab	207.08b	211.58a	54.58a	3.68bc	65.45a
4(2)1425	410.84a	198.75a	174.71c	233.00a	34.25bc	3.65c	64.25b
92B/00061	358.42ab	67.25c	229.50a	100.29d	33.04c	3.60c	64.58ab
96/01632	290.290c	103.13bc	147.71d	145.50c	42.38abc	3.63c	64.73ab
96/0603	378.54a	147.04ab	211.38b	198.33b	51.29a	3.78a	64.48b
TME1	325.13bc	135.63b	168.79c	184.50bc	48.88ab	3.75ab	64.43b
Mean	360.65	134.80	189.86	178.87	44.07	3.68	64.65
R-Square	0.92	0.91	0.99	0.95	0.84	0.90	0.73
C.V	5.45	15.08	2.074	8.79	12.78	0.95	0.56
Std Dev	46.12	45.80	29.65	47.50	9.60	0.08	0.471
Range	290.29-410.84	67.25-198.75	147.71-229.50	100.29-233.00	33.04-54.58	3.60-3.78	64.25-65.45
P of Clone	**	*	***	*	*	*	NS

Each value represent mean of three replicates.

Mean values having the same superscript within column are not significantly different at 5% confidence level.

*P<0.05

** P<0.01

*** P<0.0001; NS Not Significant

Table 5: Pasting properties of fermented starch for 25days length of fermentation.

Varieties	Peak Viscosity (RVU)	Trough (RVU)	Break Down (RVU)	Final Viscosity (RVU)	Set Back (RVU)	Peak Time (Min)	Pasting Tempe-rature (^{o}C)
30572	360.38b	134.17a	209.96ab	167.75a	33.58b	3.78b	65.14a
4(2)1425	333.17c	98.790d	201.30b	140.33b	41.54a	3.60c	64.28a
92B/00061	342.29c	123.71b	214.50ab	165.54a	41.84a	3.91a	63.78a
96/01632	334.46c	109.00c	208.84b	149.88b	40.88a	3.77b	64.13a
96/0603	362.96b	132.59a	211.75ab	166.38a	33.79b	3.75b	64.08a
TME1	380.75a	127.92ab	228.96a	163.00a	35.09b	3.74b	64.45a
Mean	352.33	121.03	212.55	158.81	37.78	3.75	64.30
R-Square	0.94	0.98	0.76	0.95	0.87	0.95	0.61
C.V	1.91	2.58	3.51	2.39	5.87	0.81	0.82
Std Dev	18.55	13.65	10.25	10.94	4.12	0.093	0.57
Range	333.17-380.75	98.79-134.17	201.30-228.96	140.33-167.75	33.58-41.84	3.60-3.91	63.78-65.13
P of Clone	*	**	NS	*	*	*	NS

Each value represent mean of three replicates.

Mean values having the same superscript within column are not significantly different at 5% confidence level.

*P<0.05

** P<0.01

*** P<0.0001; NS Not Significant

Effect of processing on the mineral composition and antinutritional factors of orange fleshed sweet potato (*Ipomoea batatas L. Lam*) flours

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Abstract

Studies were conducted on the effect of processing on the mineral composition and antinutritional factors of flours produced from two improved orange fleshed sweet potato (OFSP) genotypes (CIP199004.2 and CIP440216) using two treatment methods (blanch and unblanched methods) The results showed that the mineral contents of both unblanched and blanched OFSP flour samples differed due to processing and varietal effect, with the unblanched flour samples having slightly higher β-carotene content value than the blanched OFSP flour samples. The β-carotene values of CIP 199004.2 flour samples were 3.48 µg/g (unblanched) and 1.54ig/g (blanched), while CIP 440216 was 5.48ig/g (unblanched) and 4.24ig/g (blanched). The iron content of the unblanched CIP 440216 had a slightly higher value of 0.84mg/g than unblanched CIP 199004.2 (0.63mg/g). The phytate content in unblanched OFSP flour samples seemed relatively higher than the blanched OFSP flour samples and may be as a result of the processing method as it affected the phytate content through leaching process. The result obtained from tannins was generally low. In effect, it seems that utilizing orange fleshed sweet potato in their raw form retains the nutrients more than in their processed form. This results shows that processing orange fleshed sweet potato into flours will affect the mineral content while the antinutritional factors will be reduced minimally.

Keywords: Orange-fleshed, Processing, Mineral content, Antinutritional factors, Flours.

Introduction

Sweet potatoes belong to the *Convolvulaceae* or morning glory plant family. it is amongst the oldest vegetables today, believed to be in consumption since centuries. At present, there are as many as 400 varieties of the vegetable, with the flesh ranging from white and yellow to orange in color and the thin skin being white, yellow, orange, red or purple[1] (www.whfoods.org) .

Orange fleshed sweet potato (*Ipomoea batatas L. Lam*) is one of the most promising plants sources of β-carotene which are believed to represent the least expensive, year-round source of dietary vitamin A available to rural poor families. In Eastern and Southern Africa, orange fleshed sweet potato (OFSP**)** is grown mainly for food security and it is a very good source of beta-carotene [2] Roots (2003). Current varieties of OFSP contain 20-30 times more β-carotene than does golden rice; the outstanding features of orange fleshed sweet potato are the nutritional, compositional and sensory versatility in terms of its micronutrient contents and wide range of colors, taste and textures [3]. Woolfe, J. A. (1992)

The β-Carotene in orange-fleshed sweet potato (OFSP) is more readily released than that in dark-green leafy vegetables during cooking thereby enhancing bioavailability [4, 5]. β-carotene availability in sweet potato is significantly higher than that in other leafy vegetables and this could be due to the lack of chlorophylls and other carotenoids, which are found to be inhibitors of pro vitamin A absorption [6].β-carotene is considered the most important pro-vitamin A component in carotenoid rich foods [7,8].

Sweet potato contains unique root storage proteins that have been observed to have significant antioxidant capacities. In one study, these proteins had about one-third the antioxidant activity of *glutathione*-one of the body's most impressive internally produced antioxidants. This root vegetable qualified as an excellent source of vitamin A (in the form of beta-carotene), a very good source of vitamin C and manganese, and a good source of copper, dietary fiber, vitamin B6, potassium and iron. As an excellent source of vitamin A (in the form of beta-carotene) and a very good source of vitamin A, sweet potatoes have healing properties as an antioxidant food. Both beta-carotene and vitamin C are very powerful antioxidants that work in the body to eliminate free radicals. Free radicals are chemicals that damage cells and cell membranes and are associated with the development of conditions like atherosclerosis, diabetic heart disease, and colon cancer. This may explain why beta-carotene and vitamin C have

both been shown to be helpful for preventing these conditions. Since these nutrients are also anti-inflammatory, they can be helpful in reducing the severity of conditions where inflammation plays a role, such as asthma, osteoarthritis, and rheumatoid arthritis. [1]www.whfoods.org

Antinutritive factors in sweet potato include tannins, polyphenols and trypsin inhibitors. Tannins bind to both proteins and carbohydrates which have implications for commodities containing tannins, and condensed tannins are far more common, existing in the plant tissues of non grain starch staples. Their presence causes browning or other pigmentation problems in fresh foods and processed products and acts as anti nutritional factor by provoking astringent reaction in the mouth, thereby rendering the food unpalatable [9]. Tannins may decrease protein quality by decreasing digestibility and palatability. They are found in yam, sweet potato and cereals. They also interfere with iron absorption [10].

Materials and Methods

Materials: The two orange-fleshed sweet potato genotypes (CIP 199004.2 and CIP 440216) used for the experiment were obtained from the germplasm of the Sweet potato Programme, National Root Crops Research Institute (NRCRI) Umudike, Abia State; while the other ingredients (wheat flour, sugar, margarine, baking powder, vanilla essence, vegetable oil and eggs) were purchased from the Umuahia Main Market.

Preparation of materials: The orange fleshed sweet potato roots were processed using two treatments (the unblanched and blanched method). The sweet potato roots collected were washed with tap water, peeled with kitchen knives under water to reduce enzymatic browning and made into strips using the Chipping machine. Each of the striped samples was shared into two portions; one portion was unblanched, washed, drained and oven (Gallenkamp, model OV-160) dried while the other portion was blanched in hot water (900C) for 5 minutes, drained and oven dried. The dried samples were milled using Hammer mill and later sieved (0.2mm) into flour for mineral and antinutritional analysis and food formulation.

Chemical analysis: Mineral composition was analyzed in triplicates using RodriquezAmaya (1999) method for β-carotene determination, Atomic Absorption spectrophotometer for iron and zinc determination as described by Onwuka (2005), Oberleas (1973) method for tannins determination and the Folin-Denis spectrophotometeric method by Pearson (1976) for phytate was used.

Statistical analysis. Statistical analysis method used was SAS (1999) Package. Analysis of variance (ANOVA) and Fisher's Least Significance Difference (LSD) test was used to identify which of the means was significant from the others ($P<0.05$).

Results and Discussion

Chemical composition: The chemical composition of both the unblanched and blanched orange fleshed sweet potato is presented in Table 1. The mineral levels of both unblanched and blanched OFSP flour samples differed due to processing. The β–carotene values of CIP 199004.2 flour samples were 3.48 ìg/g (unblanched) and 1.54ìg/g (blanched) and CIP 440216 was 5.48ìg/g (unblanched) and 4.24ìg/g (blanched). The unblanched flour samples seemed to have a higher β -carotene content value than the blanched OFSP flour samples and this could be as aresult of the processing method and varietal difference as reported by [11]. [12] reported that β-carotene content and vitamin are sensitive to heat and / or oxidation. [11, 13, 14] reported that heat treatment in blanching may provoke some losses of carotenoids. Although the β- carotene values of blanched OFSP flour samples were lower, the inactivation of oxidative enzymes may have assisted to prevent further and greater losses.

Table 1. Mineral composition of unblanched and blanched Orange- fleshed sweet potato flour samples.

Parameter	β-carotene (ìg/g)	Iron (mg/g)	Zinc (mg/g)
CIP 199004.2U	3.48	0.63	0.24
CIP 199004.2B	1.5 4	0.51	0.20
CIP 199004.2B	5.48	0.84	0.20
CIP 440216B	4.24	0.54	0.30

CIP = International potato center.

U= Unblanched; B = Blanched

Iron content values: The iron content of the unblanched CIP 440216 had a slightly higher value of 0.84mg/g than unblanched CIP 199004.2 (0.63mg/g). The unblanched CIP 199004.2 and CIP 440216 were similar to that reported by [15]. [16] reported that these minerals are present in varying amounts depending on the variety and that they provide sufficient quantity to meet a portion of the RDA. This range reflects the varying bioavailability of iron in the OFSP flour samples. [17] and [18] reported that iron is present in non-heme forms in starchy roots, tubers, legumes, staple cereals, dairy products, egg and plant foods, and is much less available (low bioavailability) with absorption rates ranging from 2 20%. The iron content obtained from both unblanched and blanched OFSP flours falls within the mean iron requirement for growth (mg/day) as reported by [19a, b].

Zinc content values: The zinc content showed that the unblanched OFSP flour samples had slightly higher zinc content than the blanched OFSP flour, although with close range between them. Unblanched CIP 440216 had 0.40mg/g and unblanched CIP199004.2 had 0.24mg/g and the zinc content of the blanched OFSP flour samples ranged from 0.20mg/g (CIP 199004.2) and 0.30mg/g (CIP 440216) which is within the range reported by [15] while the blanched OFSP CIP 440216 corresponded with the report of [15]. The variation between the unblanched and blanched OFSP flour samples may be due to the processing method and difference in varieties as [20] reported that large variations in zinc content can be found between otherwise nutritionally similar food sources, also that food processing and preparation could also affect the zinc content of food by leaching into the cooking water or canning media during food preparation. Zinc like iron can be bound by phytate [20]; [21]. [20] reported that the relation between zinc content and absorption seems not to be valid for diets with a high content of inhibitory substances and that the content of zinc is also dependent on variety and growing location.

Antinutritive factors: The phytate and tannins levels in both unblanched and blanched OFSP flour samples are shown in Table 2. The phytate content in unblanched OFSP flour samples ranged from 1.04% (CIP 440216) to 1.06% (CIP 199004.2) while tannin was from 0.20% (CIP 440216) to 0.25% (CIP 199004.2). The blanched flour samples have phytate and tannin ranging from 0.46 0.68% and 0.14 - 0.15% respectively.

Table 2. Antinutritive factors of unblanched and blanched Orange-fleshed sweet potato flour samples.

Samples	Phytate (%)	Tannin (%)
CIP 199004.2U	1. 06	0. 25
CIP 199004.2B	0. 46	0. 15
CIP 199004.2B	1. 04	0. 20
CIP 440216B	0. 68	0. 14

CIP = International potato center.
U= Unblanched;
B = Blanched

The phytate content in unblanched OFSP flour samples seemed relatively higher than the blanched OFSP flour samples. This may be as a result of the processing method as it affected the phytate content through leaching process. The result obtained from tannins was generally low. These variations in tannic acid content of OFSP flour samples maybe as a result of the difference in varieties and the processing treatment. [22] However, reported that yams, potatoes and sweet potato are blanched to inactivate polyphenols oxidase which causes enzymatic browning and discoloration in the peeled or wounded raw tubers. The presence of tannins can cause browning or other pigmentation problems in both fresh food and processed products, and they act as antinutritional factor by provoking an astringent reaction in the mouth thereby making the food unpalatable, they also form complex proteins, precipitate proteins in the gut, reduce digestibility/ inhibits digestive enzymes and microorganisms. This has nutritional implication for both human and livestock in that there is damage to the intestinal tract through absorption of tannic acid toxicity in the gut, also interference with the absorption of iron and a possible carcinogenic effect. [23, 9, 10].

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Effect of storage condition and length of storage on the chemical composition of two varieties of orange-fleshed sweetpotato

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Abstract
Orange-Fleshed roots of two sweetpotato varieties (440293 and centennial) were stored in wooden boxes covered with river sand and sawdust; the control received no covering. Samples were chemically analysed to determine the effect of the storage materials on the composition of the sweetpotato samples. The results show that the storage methods had no effect on the means obtained for fat and fiber contents but the moisture, vitamin C, starch and total carotenoid contents were significantly affected by the storage materials. After three weeks of storage, moisture content decreased by 7.56% for samples under sand, 5.45% for samples under sawdust and 8.34% for control samples. The samples stored under sawdust showed higher retention of moisture, vitamin C and total carotenoid, than those stored under river sand and the control sample. At four weeks storage, 100% spoilage of the control samples was observed, but sawdust and river sand kept over 50% of the samples of the two varieties in storage for six weeks Visual examination of these unspoiled samples showed that they were still good enough for human consumption after six weeks of storage under river sand and sawdust. The percentage spoilage was highest in the samples under control and least in the samples stored under sawdust.

Keywords: Orange-fleshed sweetpotato, River sand, Sawdust, Biochemical composition.

Introduction

Sweetpotato is an important staple food crop grown for its edible roots and leaves as a protein-rich vegetable. Orange-fleshed sweetpotato is grown mainly for food security. Orange-fleshed sweetpotato, a naturally biofortified food, offers one of the highest sources of β- carotene (Woolfe, 1992).

Farmers consider sweetpotato to be difficult to store as a result of the threat from Cylas spp., the sweetpotato weevil. Sweetpotato roots are highly perishable and they are not generally stored for extended periods after harvest (Karuri and Ojijo, 1994). The only kind of storage regularly practiced in Nigeria is in-ground storage by which farmers keep unharvested mature sweetpotatoes in the field until they are needed for consumption or sale (Onwueme, 1982). However, after maturation pest infestations by sweet potato weevil become severe and cause production losses of up to 50% (Ndamage, 1988). Traditional storage in underground pits or baskets and covering with grasses has been reported in Uganda, Kenya and Malawi (Devereau and Bockett, 1994). Spoilage is common with these storage methods.

Fresh sweetpotato can be stored for several months using artificial air conditioned stores (Picha, 1987). But rural farmers cannot afford these stores, hence simple and cheap storage methods are needed. There is also need to know the effect of the storage methods on the nutritional composition of the roots especially on the total carotenoid content of the orange-fleshed sweet potato. Moreover, the need to ensure nutrient retention during storage cannot be over-emphasized. This study was carried out to determine the effect of different traditional storage methods on the nutritional composition of two orange-fleshed sweetpotato varieties.

Materials and Methods

The 440293 and centennial varieties of orange-fleshed sweetpotatoes were obtained from the Sweetpotato Programme of the National Root Crop Research Institute, Umudike. The two varieties of orange-fleshed sweetpotatoes (440293 and Centennial orange-fleshed) were sorted to remove spoilt roots, and wrapped in tagged black polyethene bags and exposed to the sun at 30°C for 5 days (for curing) after which the roots were treated with wood ash. The roots were divided into three lot and stored in wooden boxes measuring 75cm x 75cm x 30cm. Dry sawdust / sand were spread evenly to form a 10cm deep bed and the roots were arranged on the beds before completely covering them with more sand / sawdust as the case may be. The third group was left without any covering (control). The storage boxes were left in a dark room under ambient temperature and samples were drawn from the lots weekly. Physical and chemical evaluations were used to monitor the quality changes in the stored roots and the number of roots that spoilt during storage were noted. The

samples were evaluated for moisture, starch, ash, fibre, and fat using the AOAC (1990) methods. The total carotenoid was determined with the HarvestPlus method. The stored roots were examined at regular intervals to check for rotting and shriveling. The statistical analysis was carried out using the 1999 version of the Statistical Analysis System (SAS). Analysis of variance (ANOVA) was carried out on the data obtained from the chemical analysis. Mean separation was done using Fisher LSD to determine significant differences ($P<0.05$).

Results and Discussion

Table 1 shows the biochemical composition of two varieties of orange fleshed sweetpotato (440293 and Centennial) before storage. Tables 2 and 3 show the chemical compositions of 440293 and centennial varieties of orange-fleshed sweetpotatoes respectively, stored under 3 different conditions.

In the 440293 variety, the storage methods did not cause any significant difference in the fat content. There was no significant ($p>0.05$) difference in the moisture content for the first 2 weeks in all the storage methods but in the 3rd week there were significant differences ($p<0.05$) in the moisture. After three weeks of storage, moisture content decreased by 7.56% for samples stored under sand, 5.45% for samples under sawdust and 8.34% for samples without any covering (control); this reduction may be due to dehydration (Ojijo, 1991). Starch content increased by 7-14% after three weeks of storage, this may be attributed to the conversion of sugars to starch (Picha, 1987). Samples stored under sawdust showed highest retention for moisture, vitamin C and total carotenoid, while the control had the least retention.

For the centennial orange-fleshed sweetpotato, the storage methods did not have any significant effect on the fat and fibre contents for the three weeks of storage. Moisture, starch and total carotenoid contents were significantly affected by the storage methods. Moisture content decreased by 6.70% under sand storage, 8.35% under sawdust storage and 16.06% under storage without covering (control). Starch content increased by 0.47%, 5.61% and 6.51% under sand, sawdust and control, respectively. There was no significant difference in vitamin C content of the samples under the different storage conditions. The samples stored under sawdust also showed the highest retention of the chemical components.

Figures 4 and 5 show the percentage spoilage recorded over six weeks of storage. It was observed that perishability differs among varieties in agreement with report from Woolfe (1992). Storage without covering (control) was inefficient and all the roots spoilt after 3 weeks of storage. The spoilage started with brown patches and then total rot. The roots stored under sawdust spoilt the least.

Conclusion

The results of the experiment showed that the sweet potatoes under layers of sawdust preserved better than those stored under river sand. The samples under sawdust also retained their chemical compositons better than those stored under river sand and control. So sawdust is a better storage material than river sand. These simple storage methods can be used to extend the shelf life of the perishable Orange fleshed sweet potato.

Table 1: Chemical composition of 2 varieties of orange fleshed sweet potato before storage.

Samples	moisture content (%)	Ash (%)	Fibre (%)	Fat (%)	Starch (%)	Vitamin C (mg)	Total Carotenoid (µg/g)
440293	76.00	1.09	0.44	4.19	12.00	2.35	5.18
centennial	71.00	1.77	0.28	4.37	10.60	2.60	5.43

Table 2: Effect of storage method on the chemical composition of 440293 (orange-fleshed sweetpotato).

Storage method	Moisture content (%)	Ash (%)	Fat (%)	Fibre (%)	Starch (%)	Vitamin C (mg/100g)	Total carotenoid (µg/g)
Week 1							
Sand	74.026^{a}	1.307^{ab}	0.185^{a}	0.400^{a}	11.585^{b}	2.410^{a}	5.187^{b}
Sawdust	75.202^{a}	1.456^{a}	0.160^{a}	0.280^{b}	11.190^{c}	2.410^{a}	5.719^{a}
Control	72.448^{a}	1.166^{b}	0.150^{a}	0.360^{a}	12.000^{a}	2.240^{a}	5.017^{b}
Week 2							
Sand	70.034^{a}	1.180^{b}	0.185^{a}	4.430^{a}	12.505^{b}	2.120^{b}	5.061^{a}
Sawdust	71.687^{a}	1.511^{a}	0.225^{a}	0.350^{a}	12.760^{b}	2.340^{a}	5.100^{a}
Control	68.754^{a}	1.039^{b}	0.240^{a}	0.440^{a}	13.750^{a}	2.000^{b}	5.010^{a}
Week 3							
Sand	68.433^{b}	1.314^{b}	0.185^{a}	0.420^{b}	12.505^{b}	1.900^{ab}	5.003^{a}
Sawdust	71.106^{a}	1.503^{a}	0.220^{a}	0.370^{b}	12.780^{b}	2.175^{a}	5.084^{a}
Control	66.404^{c}	1.028^{c}	0.190^{a}	0.545^{a}	13.750^{a}	1.600^{b}	4.977^{a}

Means with the same subscript down the columns are not significantly different ($p<0.05$)

Table 3: Effect of storage method on the chemical composition of centennial (orange-fleshed sweetpotato).

Storage method	Moisture content (%)	Ash (%)	Fat (%)	Fibre (%)	Starch (%)	Vitamin C (mg/100g)	Total carotenoid (µg/g)
Week 1							
Sand	66.040^{a}	1.497^{a}	0.270^{a}	0.295^{a}	9.275^{a}	2.155^{b}	5.247^{b}
Sawdust	62.593^{b}	1.709^{a}	0.215^{a}	0.270^{a}	10.140^{a}	2.265^{b}	5.646^{a}
Control	62.375^{b}	1.141^{b}	0.225^{a}	0.210^{a}	9.730^{b}	2.555^{a}	5.071^{c}
Week 2							
Sand	64.080^{b}	1.714^{a}	0.305^{a}	0.350^{a}	10.650^{b}	2.075^{a}	5.229^{a}
Sawdust	64.714^{a}	1.644^{a}	0.290^{a}	0.310^{a}	11.195^{a}	1.945^{a}	5.394^{b}
Control	60.873^{c}	1.328^{a}	0.280^{a}	0.340^{a}	11.290^{a}	1.925^{a}	5.032^{a}
Week 3							
Sand	64.298^{a}	1.721^{a}	0.345^{a}	0.350^{a}	10.650^{b}	2.080^{a}	5.200^{a}
Sawdust	65.068^{a}	1.637^{a}	0.340^{a}	0.315^{a}	11.195^{a}	1.885^{a}	5.292^{a}
Control	59.597^{b}	1.343^{b}	0.355^{a}	0.390^{a}	11.290^{a}	1.925^{a}	5.186^{a}

Means with the same subscript down the column are not significantly different ($P<0.05$)

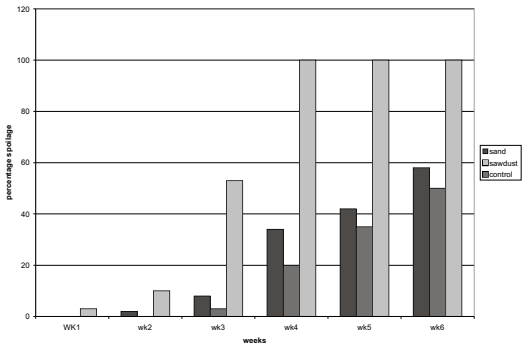

Figure 1: Percentage Spoilage Recorded For 440293 Variety

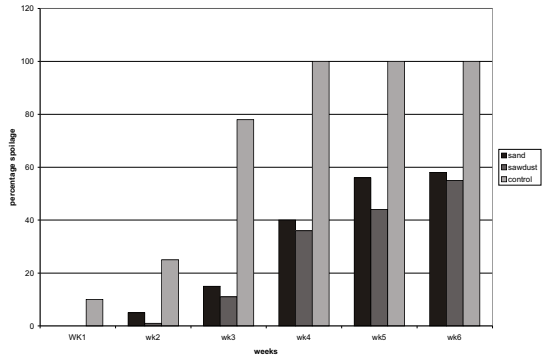

Figure 2: Percentage spoilage recorded for centennial orange fleshed sweetpotato.

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New approaches for quantifying carotenoids content in cassava roots

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Abstract
Cassava is an ideal vehicle for delivering pro-vitamin A carotenoids to human populations affected by deficiency of this important micronutrient. Rapid cycling recurrent selection has proven to be very effective increasing carotenoids levels in cassava. The maximum level of total carotenoids increased by about 3 µg / g of fresh root each year. As breeding populations evolve large populations are developed and the selection among them becomes increasingly difficult because most genotypes show intense yellow coloration in their roots. Reflectance colorimeter and NIRS were evaluated as potentially useful alternatives to select those roots that will be analyzed through spectrophotometer and/or HPLC. Results indicate that both equipments can help in the selection process.

Keywords: Reflectance colorimeter; near infrared spectrophotometer; NIRS

Introduction

Vitamin A is an essential micronutrient for the normal functioning of the visual and immune systems, growth and development, maintenance of epithelial cellular integrity and for reproduction (ACC/SCN. 2000; Combs, 1998). Improving the vitamin A status of children reduces mortality rates by 23% to 30% (ACC/SCN, 1992; Beaton et al., 1993). It is estimated that 75 to 251 million children have sub-clinical symptoms (WHO 2009). In addition to the direct effect of VAD, there is growing evidence of vitamin A having synergistic effects with iron and zinc bio-availability (Graham & Rosser, 2000). Carotenes from vegetables contribute two-thirds of dietary vitamin A, worldwide, and more than 80% in the developing world (Combs, 1998).

Three main strategies have been traditionally used to prevent VA deficiency: dietary diversification, food fortification and/or supplementation. These strategies are relatively cost-effective, but have failed to completely eradicate the problem for a diversity of reasons (West, 2003). Recently, different programs (HarvestPlus, AgroSalud) involving a global alliance of research institutions initiated the development of a fourth strategy (biofortification) to develop micronutrient-dense staple crops (Hirschi, 2008; Pfeiffer & McClafferty 2007a, b). Among these initiatives is the development of biofortified cassava varieties with high pro-VA contents in the roots. Biofortification can be achieved through conventional breeding techniques that take advantage of the genetic variability for micronutrients in different crops (Latham MC, 2003; Welch RM, 2002; Chávez et al., 2005). In addition, several studies are gradually contributing to a better understanding of carotenoid retention in different biofortified crops (Li et al., 2007; Chávez et al., 2008; van Jaarsveld et al., 2006). Recent studies are also contributing to our understanding of the efficiency of carotenoid conversion present in cassava (*Manihot esculenta Crantz*) roots and other crops into VA (Thakkar et al., 2007; 2009; Failla et al., 2008; Liu, 2009; van Jaarsveld et al., 2005). Iglesias et al. (1997) and Chávez et al., (2005) screened a relatively large sample of clones for their carotenoids and other micronutrients contents. They suggested that there was enough genetic variability to justify a breeding project to increase carotenoids contents in cassava roots.

Cassava breeding is typically based on phenotypic mass selection. Hand pollinations among elite germplasm are made to produce full-sib progenies. Alternatively polycross nurseries can be planted for open pollinations that result in half-sib families (Ceballos et al, 2007; Kawano, 1980). Seed from segregating progenies are then germinated and grown successively in F1 nurseries, Clonal Evaluation Trials (CET), Preliminary Yield Trials (PYT), Advanced Yield Trials (AYT) and, finally, multi-location Regional Trials (RT). Throughout this process there is no sexual reproduction and therefore there is no recombination, nor segregation in the materials under selection. The selection scheme, therefore, is a 6-8 years, tandem process. F1 nurseries for a target environment may have 4000-5000 genotypes. Number of genotypes gradually reduces to 1500-2500 in CETs; to 150-300 in PYTs; 80-120 in AYT; and 20-30 in RT (Ceballos et al, 2004; 2007; Jennings and Iglesias, 2002).

This lengthy evaluation and selection scheme

is due to the low multiplication rate of cassava. On average only 7 to 10 cuttings can be obtained per plant. It takes, therefore, several years to produce enough planting material to conduct replicated trials at several locations. Cassava breeders typically concentrate on high heritability traits (i.e. disease resistance or harvest index) in earlier stages of the selection process and gradually shift the emphasis to low-heritability traits (i.e. fresh root yield) in the later stages (Ceballos et al, 2004; 2007; Jennings and Iglesias,2002; Kawano,2003; Kawano et al., 1998). Given the urgency to develop biofortified cassava cultivars a rapid cycling recurrent selection system was implemented to take advantage of the relatively high heritability for carotenoids content in cassava roots (Morillo et al., 2009). Two alternatives (reflectance colorimeter and near-infrared spectroscopy, NIRS) have been suggested for quantifying carotenoids in different crops (Ameny and Wilson, 1997; Ruiz et al., 2008)

The objective of this study was to evaluate alternative methods to screen for high-carotene contents in segregating progenies in the process of selection to increase carotenoids content in cassava roots.

Materials and Methods

Germplasm: A large number of progenies segregating for high-carotene content was developed by the cassava-breeding project at CIAT. Crosses involved more than 50 different elite progenitors and the botanical seed generated was germinated in three different batches (1568, 1674 and 1837 seedling plants, respectively) and transplanted to the field from June to August 2009. Harvest took place in three batches in May, July and August, 2010.

Sampling procedure: The plants were harvested and three commercial-size roots were selected to represent the respective genotype. Roots were washed, peeled and cut along their longitudinal axis in four quarters. Two opposed quarters from each root were taken and combined with those from the other two roots from the same genotype. The combined quarters were then chopped with a stainless steel knife. The combined sample was then used for carotenoids quantification (both using the spectrophotometer and HPLC), readings from colorimeter and NIRS, quantification of the cyanogenic potential and dry matter content measurements (oven drying method).

Reflectance colorimeter readings: Before roots were cut in the quarters three reading were taken with a Konica Minolta Chromameter CR 410 ("colorimeter") in mid sections of the root. After combining and chopping the six longitudinal quarters from the roots of each genotype about 200 grams of chopped root were placed in a plastic bag and three readings were also taken on that sample (Figure 1). Results of the readings from the colorimeter were averaged.

Near infrared spectrophotometer (NIRS) readings: As readings were made on the colorimeter two different subsamples of the chopped fresh roots of each genotype were placed in the sample capsules for NIRS **(**Foss, Model 6500**)** measurements**.** Predicted values of the two NIRS readings were averaged.

Carotenoid extraction: Carotenoids were extracted following the method suggested in the literature (Rodriguez-Amaya, 2001; Rodriguez-Amaya et al., 2004), except that separation of the solid and liquid phases was carried out by centrifugation and not by filtration (Chávez et al., 2005). Approximately 5 g of fresh root tissue were homogenized for 1 min with 10 mL acetone: petroleum ether (1:1) using a Polytron homogenizer (IKA T18, Staufen, Germany), followed by centrifugation (Eppendorf 5804R, Hamburg, Germany), at 3000 RPM, for 10 min, at 4 ºC. The liquid phase was collected and extraction of the residue, followed by centrifugation, was repeated until it turned colorless (usually 3 times). The extracts were then combined with 10 mL of 0.1 M NaCl solution and the petroleum ether phase containing the carotenoids separated from the lower aqueous-acetone phase.

Carotenoid quantification: With the extracts obtained, total carotenoid content (TCC) was determined by visible absorption spectrophotometry (Cecil CE2021, Cambridge, UK), at an absorbance at 450 nm and using the absorption coefficient of -carotene in petroleum ether (2592) (Rodriguez-Amaya, 2001; Rodriguez-Amaya et al., 2004). All-trans-ƀ-carotene (TBC) quantification was done by HPLC. From the petroleum ether solution used for spectrophotometric quantification of total carotenoid, aliquots (15 mL) were taken, partially dried by rota-evaporation (Laborota 4000, Schwabach, Germany) and completely dried with nitrogen. Immediately before injection, the dry extract was dissolved in 1 mL of Methanol:Methy tert-butyl Ether (1:1)

HPLC-grade and filtered through a 0.22 µm PTFE syringe filter. Separation and quantification of carotenoid were achieved using an YMC Carotenoid S-5 C30 reversed-phase column (4.6 mm X 150 mm: particle size, 5 ìm), with a YMC Carotenoid S-5 guard column (4.0 x 23 mm) in a HPLC system (Agilent Technologies 1200 series, Waldbronn, Germany), using DAD detector with wavelength set at 450 nm. Peaks were identified by comparing retention time and spectral characteristics against a pure standard and available literature. Quantity was determined by comparison of peak area against a standard curve prepared with known concentrations of all-trans-b-carotene. TCC and TBC were estimated on a fresh (TCC-FW and TBC-FW) and dry weight (TCC-DW and TBC-DW) basis.

Results and Discussion

From the original sample of about 5000 genotypes many were discarded in the field because of the absent or low level of pigmentation of their roots (Table 1). A total sample of 532 genotypes was processed in the laboratory and generated complete data from the colorimeter, NIRS, spectrophotometer and HPLC equipments. However, some samples were discarded because of their low dry matter contents. Results reported in this article relate to data from the sample ranging between 472 and 491 genotypes depending on the variables considered. The total number of genotypes in the field was 5079. Visual selection was made in the field eliminating genotypes whose roots were white, cream or light yellow (except for batch 1 when all genotypes were processed to obtain more information on the improvement of the predicting equation for the NIRS). Roots from 58% of the genotypes were harvested and sent to the laboratory. Further and more careful selection of roots based on visual assessment of intensity of pigmentation reduced the number of genotypes to 30% of those in the field. Results from the NIRS allowed reducing the number down to 10% of the 5079 genotypes originally planted in the seedling nursery.

To speed up the progress a rapid-cycling recurrent selection process was implemented at CIAT. Crosses among high-carotene sources were made and the resulting seed germinated, transplanted to the field and evaluated in seedling nurseries. Selected F1 plants were then used in crossing block to generate a new cycle of selection. Some of the recombinant seed could be harvested within a year (therefore the recurrent selection cycle would last two years: one for evaluation and the other for seed production) but large number of seed will be harvested during the second year of crossing nursery (in this case the length of the cycle would be three years). **Figure 2** illustrates the progress observed in total carotenoids content as measured in the seedling nurseries from 2005 through 2010. In spite of the fact that the data from **Figure 2** are based on single-plant plots, the high heritability for carotenoids content in cassava roots, help to highlight its reliability. It has to be clarified that germplasm evaluated each year does not come from crosses of the selected clones in the year immediately before. The length of the breeding cycle, as explained above ranged from 2 to 3 years.

Table 1. Number of genotypes evaluated in the three batches of evaluations conducted for quantifying carotenoids contents in cassava roots.

Batch	Field	Laboratory	NIRS	HPLC
1	1568	1568	600	144
2	1674	480	271	153
3	1837	914	667	235
Total	5079	2962 (58%)	1538 (30%)	532 (10%)

Results of the evaluation for carotenoids content in the 2010 seedling nursery at CIAT are presented in Table 2. These are results of single plant evaluations. There is an excellent correlation between single plant evaluations at the seedling stage and those for the same genotypes at later stages in the selection process (e.g. clonal evaluation trials or preliminary yield trials). Results in fresh weight and dry weight basis are presented. Dry weight basis data was generated by considering the dry matter content of the samples. This is not necessarily equivalent to results that may be obtained by first drying the sample and then measuring the carotenoids. It is, however, an acceptable way to produce data that may help compare results from different research teams.

Data generated through the HPLC quantifications of carotenes was contrasted with readings with the colorimeter and the NIRS. In this comparison several samples that had lower than 20% dry matter content were not considered. Therefore these estimates are based on a sample of

478 observations. The colorimeter generates three readings "a", "b" and "L". A fourth variable ("h2") was created using the arctangent (ATAN2) function of Excel, relating the "a" and the "b" readings of the colorimeter. Different analyses were made and preliminary results suggested that the best associations were found between carotenoids content with "a" and "h2" parameters. Figures 3 and 4 illustrate the relationship between these parameters and all-trans β-carotene of each sample.

Table 2**.** Results from the evaluation for carotenoids content (fresh weight bais) in a sample of 491 cassava genotypes. Numbers within parenthesis refer to data transformed to express carotenoid values in a dry weight basis

	Dry matter content	Total carotenoids content	b-carotene content	All-trans β-carotene content
Parameter	(%)	(µg/g)	(µg/g)	(µg/g)
Count	472	491 (459)	491 (459)	491 (459)
Maximum	46.7	24.7 (96.8)	19.1 (67.3)	16.5 (61.5)
Minimum	20.2	1.6 (4.5)	1.5 (4.2)	0.9 (2.5)
Average	30.2	11.6 (38.8)	9.9 (32.9)	8.2 (27.3)
St. Deviation	5.3	3.4 (13.4)	2.7 (10.5)	2.6 (9.8)
Clones with e10.0 (40) ug		340 (189)	231 (108)	100 (44)
Clones with e12.5 (50) ug		172 (88)	68 (24)	22 (8)
Clones with e15.0 (60) ug		57 (30)	13 (7)	4 (2)
Clones with e17.5 (70) ug		17 (12)	4 (0)	0 (0)

There is a clear association between the "a" and "h2" parameters and all-trans β-carotene content. Both linear and exponential regression analyses were performed for in figures 3 and 4. In every case R^2 values ranged between 0.60 and 0.70. In both cases the exponential relationship was better than the linear one. In spite of the good correlation the use of the colorimeter is not precise enough to replace the use of the spectrophotometer and/or HPLC. It is feasible, however, to use the colorimeter to select those samples that will be further analyzed in the laboratory. Using the colorimeter is fast (could even be used in close to the field where cassava has been grown), simple and the cost of equipment is not prohibitive. As the breeding project advances there will be more and more need to rely on a more efficient way to assess intensity of pigmentation and the colorimeter may be an interesting alternative to the human eye.

The association between NIRS and all-trans β-carotene content is presented in figure 5. As in the case of results from the colorimeter both the linear and exponential relationships were determined, with R^2 values ranging from 0.65 to 0.72, respectively. As for the case of the colorimeter results are not precise enough to replace spectrophotometer and/or HPLC data, and can only be use to pre-screen what will be analyzed in the laboratory. The advantage of the NIRS is that the prediction equation can be improved through several iterations where new data is added (particularly as new materials with higher

carotenoid levels are produced). The equipment, however, is expensive and it is probably not recommendable that it is transported close to the production area.

Conclusions

- There has been a very significant increase in the levels of carotenoids content during the last few years. Results suggest (as already demonstrated) high heritability values for carotenoids content.
- Rapid cycling recurrent selection for high-carotene in cassava roots has been proven to be an efficient breeding method and the gains from selection presented are probably the first to demonstrate this kind of responsiveness in cassava.
- The colorimeter and NIRS equipment are useful for selection those clones with better probability of having high-carotene values. Results, however, are not precise enough as to replace data from spectrophotometer or HPLC.
- The costs of colorimeter and NIRS are very contrasting with the former being about 10% of the latter. However, NIRS predicting capacity can be improved as additional data is added.
- Colorimeter data was used to generate the figures shown. Colorimeter data was not used to predict the values (as was the case with NIRS) of carotenoids. It will be interesting to see the predicting capacity of the colorimeter in a new data set.

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Figure 1. Illustration of the Minolta colorimeter and the way it was used in the screening of fresh cassava roots samples.

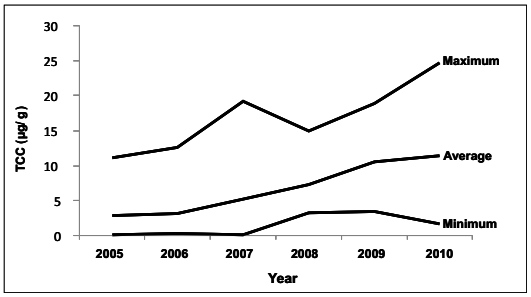

Figure 2. Progress increasing carotenoids contents in fresh root samples of seedling nurseries from 2005 to 2010..

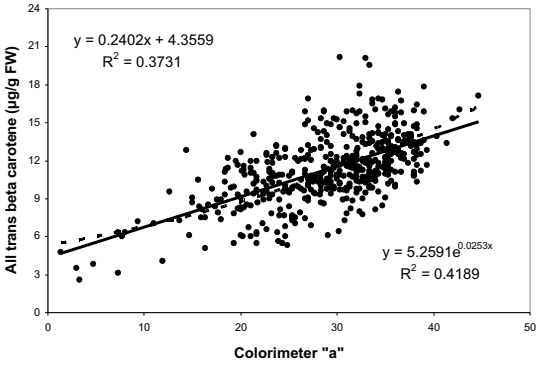

Figure 3. Relationship between the "a" lecture of the colorimeter and all-tras β-carotene content (fresh weight basis) in root samples from 478 cassava genotypes. Linear (full line) and exponential (doted line) regressions were estimated.

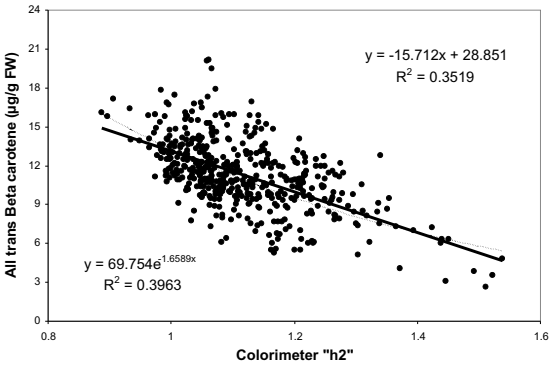

Figure 4. Relationship between the "h2" lecture of the colorimeter and all-tras β-carotene content (fresh weight basis) in root samples from 478 cassava genotypes.

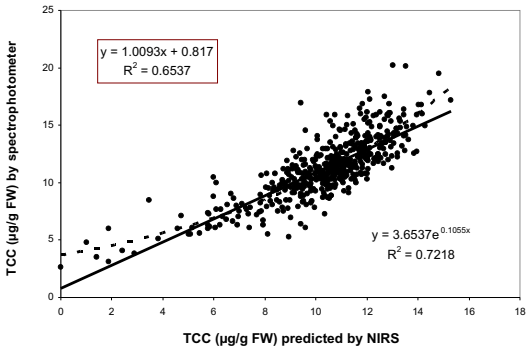

Figure 5. Relationship between the NIRS lecture and total carotenoids content (fresh weight basis) in root samples from 478 cassava genotypes.

Optimizing brewer spent grain addition and extrusion variables of yam starch based extruded pasta using Box Benkhen design

O.P. Sobukola, O. Ogunsade and L.O. Sanni

Abstract

Response surface methodology based on Box Behnken design was used to optimize brewer spent grain (BSG) level and extrusion variables during production of a yam-starch based pasta. The effect of BSG level (5-15%) and extrusion variables namely, barrel temperature (100-1100C) and screw speed (100-140rpm) on the responses such as water absorption index (WAI), solubility index (SI), lateral expansion (LE), bulk density (BD) and dietary fibre (DF) of the extruded pasta was investigated. Seventeen different combinations including five replicates of the centre points were performed in random order based on the design for three factors. Yam starch extracted from Dioscorea rotundata and dried, milled and sieved BSG was used for the experiment to develop a pasta product. Different levels of starch to BSG (95: 5, 90:10, 85:15) were blended at single moisture content /feed moisture (75ml/100g) and then extruded using a single screw extruder. Data obtained were subjected to statistical analysis using ANOVA at 5% level while least square method was used for modelling the second order polynomial model. The WAI, SI, LE, BD and DF of the yam starch based pasta varied between 2.29 and 2.59g gel/g; 0.36 and 2.23%; 0.97 and 1.25%; 5.63 and 6.30g/cm3; and 2.30 and 2.74%, respectively. The coefficient of determination (R2) and F- ratio of the model for the responses varied between 0.58 and 0.79, and 1.09 and 2.87, respectively. The product responses are significantly affected by the process variables but the effect of temperature was more pronounced. An increase in BD, SI and DF of the pasta was observed when BSG level increases with while WAI and LE of the product increases with increase in temperature and screw speed. DF and BD were observed to increase with temperature but decreases with screw speed, while SI decreases with increase in temperature but increases with increase in screw speed. The optimum processing conditions for the pasta were found to be a barrel temperature of 104-1050C, screw speed of 110-111rpm and BSG level of 13-14%.

Keywords: Yam starch, brewer spent grain, extrusion, optimization

Introduction

Yam are perennial herbaceous vines cultivated for the consumption of their starchy tubers in Africa, Asia, Latin America and Oceania with hundreds of cultivars among the cultivated species. They are high in carborhydrate, Vitamin C, dietary fiber, Vitamin B6, potassium, and manganese but low in saturated fat and sodium (Holford, 1998). The fresh yam tuber is processed and consumed in different forms including boiled, pounded, mashed, baked, roasted and so on (Kordylas,1990). Starch is the most important carbohydrate in the human diet and is contained in many staple foods including yam. Widely used prepared foods containing starch are bread, pancakes, cereals, noodles, pasta, porridge, and tortilla (Eliasson, 2004). Sources of commercial starches include corn, wheat, potato, rice, cassava, sweet potato, cannas, arrowroot, and yam (Cargill et al., 2003). Brewers spent grain (BSG), the main by-product of the brewing industry and the most abundant brewing by-product, corresponding to around 85% of total by-products generated (Reinold, 1997), is a rich source of dietary fibre and it also contains protein and phenolic compound (Ozturk et al., 2002). Food extrusion is a process in which a food material is forced to flow, under one or more varieties of conditions of mixing, heating and shear, through a die which is designed to form and/or puff-dry the ingredients (Rossen and Miller, 1973). Extrusion cooking process can cause starch gelatinization, protein denaturation, inactivation of raw food enzymes, destruction of naturally occurring toxins, diminishing of microorganisms in the final product, e.t.c.(Harper, 1981).

Response surface methodology (RSM) is a collection of statistical and mathematical techiniques useful for developing, improving and optimizing processes in which a response of interest is influenced by several variables and the objective is to optimize this process (Bas and Boyaci, 2007; Anjum et al., 1997). Apart from its high nutritional value and fibre content, BSG is a low cost ingredient that can be used in foods. The aim of the research was to optimize the process conditons and investigate the effects of BSG level and extrusion variables on some properties of yam - starch based pasta .

Materials and methods

White yam (Dioscorea rotundata) was purchased from a local market while food grade BSG was obtained from Sona Breweries, Sango Ota, Ogun State, Nigeria and analysed. A single screw extruder was used.

Yam starch and Brewers spent grain (BSG) preparation: Yam starch was extracted from the tubers using the method of Daiuto et al. (2005). The spent grain was dried at 60oC to avoid development of undesired flavour, milled and then sieved. Starch: BSG ratios (95:5, 90:10and 85:15) was mixed using a mixer (PMK-8710N, Panasonic, Japan).

Extrusion: A single screw extruder with L/D ratio of 304mm: 18.5mm, screw diameter of 18mm and power of 0.25hp was used. It was operated at full speed in all runs under the conditions shown in Table 1. The pasta produced was cooled to room temperature and sealed in polyethylene bags until measurements were taken.

Analysis of samples: Lateral expansion of the pasta was determined using the method of Alvarez Martinez et al. (1988) and Fan et al.(1996). The water absorption index (WAI) and solubility index (SI) was determined using the method of Anderson et al. (1969). The bulk densty was determined using the method of Ali et al. (1996) while the dietary fibre of the pasta was determined using the method of Englyst (1997). Experimental design and Statistical Analysis: A three factor Box Behnken design was used as shown in Table 1 with seventeen combinations including five replicates of centre point. A second order polynomial model for the dependent variables as shown in equation 1 was established to fit the experimental data. An ANOVA test was carried out using design expert 7.0 to determine level of significance at 5% level.

$$Y = \beta_o + \sum_{I=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^{\,2} + \sum \sum_{i<j=1}^{3} \beta_{ij} X_i X_j + \varepsilon \quad (1)$$

Where Y is the response, bo is a constant while bi, bii and bij are linear, quadratic and interaction coefficients; and e is error.

Results and Discussion

The BSG was observed to be high in carbohydrate (60.64 g/100g), protein (24.39 g/100g) and fibre content (9.19g/100g). RSM was used to optimize the extrusion cooking conditions in order to obtain high quality yam starch based pasta. Y1, Y2, Y3, Y4, and Y5 ranged between 2.29 and 2.59, 0.36 and 2.73, 0.97 and 1.25, 5.63 and 6.30, and 2.38 and 2.74, respectively. The regression coefficients of the pasta are shown in Table 2 and vary between 0.584 and 0.787; and the F-ratio value was between 1.09 and 2.87. The model of Y1 (R2=0.678) of the pasta has a significant quadratic term of the screw speed.

Figure 1 shows the surface and contour plots of Y1 as a function of X2 and X1 at a constant X3. An increase in screw speed increases Y1 as high speed results into intense shearing which will lead to higher gelatinization or mechanical destruction of starch molecules in the samples giving rise to more water holding capacity. Y2 response model (R2=0.787) has a significant temperature termwhile figure 2 shows the surface and the contour plots of Y2 as a function of X2 and X1 at constant X3 level. Solubility index increases as screw speed increases and decreases with increase in temperature (Ainsworth, 2007; Alton et al., 2008) The response surface model of Y_3 has R^2 of 0.584. For surface and contour plots, as shown in Figure 3, Y_3 increased with increase in screw speed and barrel temperature. Y_4 increases with increase in temperature, but decreases with increase in screw speed as shown in Figure 4. The response surface model of dietary fibre has R^2 of 0.79. The significant model terms are interaction term (temperature and screw speed) and the quadratic term of screw speed. From figure 5, dietary fibre increases with increase in temperature and decreases with increase in screw speed. This trend shows that the dietary fibre content in pasta is readily available at lower speed than at higher screw speed.

Conclusion

The product responses investigated was mostly dependent on temperature and screw speed rather than BSG level. Increasing temperature and screw speed increases WAI and SI. However, lateral expansion increases with increase in screw speed and decrease in temperature and BSG level. Changing process conditions affected the functional properties and dietary fibre content of the attributes. Using temperature of 104 105°C, screw speed of 110 111 rpm and BSG level of 13 14% produces pasta of acceptable properties.

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Table 1. Coded levels for the Box Behnken design

		Levels	
Variables	-1	0	+1
Temperature (°C)	100	105	110
Screw speed (rpm)	100	120	140
BSG level (%)	5	10	15

Table 2 : Coefficients of regression with respect to process variables

Coefficient	Y_1	Y_2	Y_3	Y_4	Y_5
a_o	2.47	1.20	1.05	5.98	2.65
a_1	0.063	-0.45*	0.041	0.023	0.073
a_2	0.028	0.36	0.03	-0.064	0.075
a_3	-0.0007	0.24	-0.036	0.13	0.012
a_{11}	0.029	-0.33	0.014	-0.17	0.12
a_{22}	-0.028*	0.22	-0.046	0.16 -	0.019*
a_{33}	-0.015	0.10	0.011	-0.049	0.074
a_{12}	-0.037	0.31	0.03	-0.012	-0.096*
a_{13}	-0.091	-0.29	-0.049	-0.029	-0.12
a_{23}	-0.008	-0.28	0.000075	-0.10	0.027
R^2	0.678	0.786	0.584	0.624	0.787
F -ratio	1.64	2.87	1.09	1.29	2.88
P value	0.14	0.30	0.55	0.85	0.32
Lack of fit value	3.38**	1.75**	0.81**	0.26**	1.63**

*significant at 5% level; a_o-intercept,a_1 a_{23} are regression coefficients, Y_1-water absorption index, Y_2-solubility index, Y_3-lateral expansion, Y_4-bulk density and Y_5-Dietary fibre; ** Not significant at 5% level

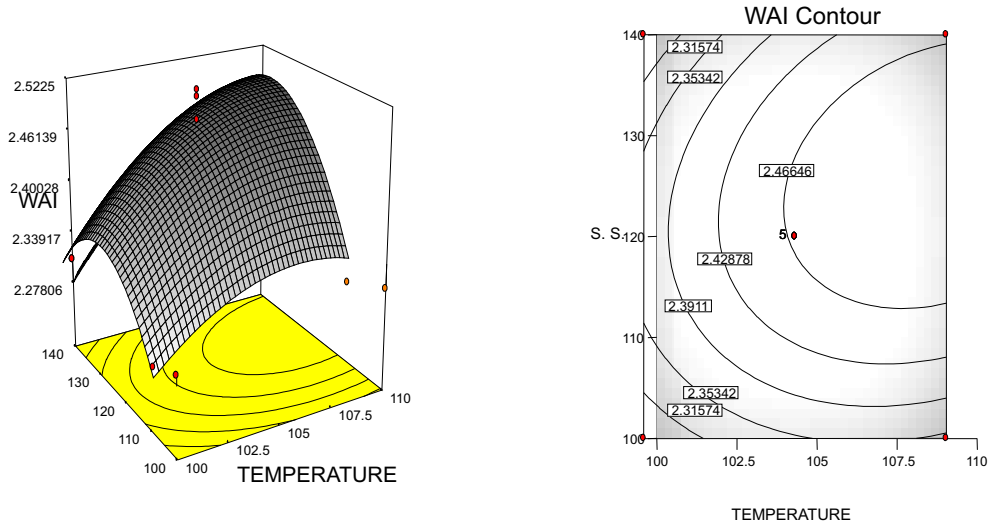

Figure 1. Response surface and contour plots of Water Absorption Index as a function of screw speed and temperature constant BSG level

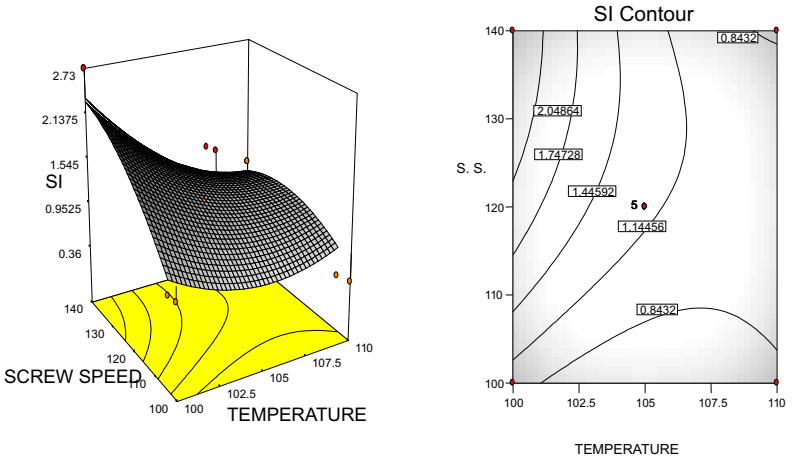

Figure 2. Response surface and contour plots of Solubility Index as a function of screw speed and temperature at constant BSG level

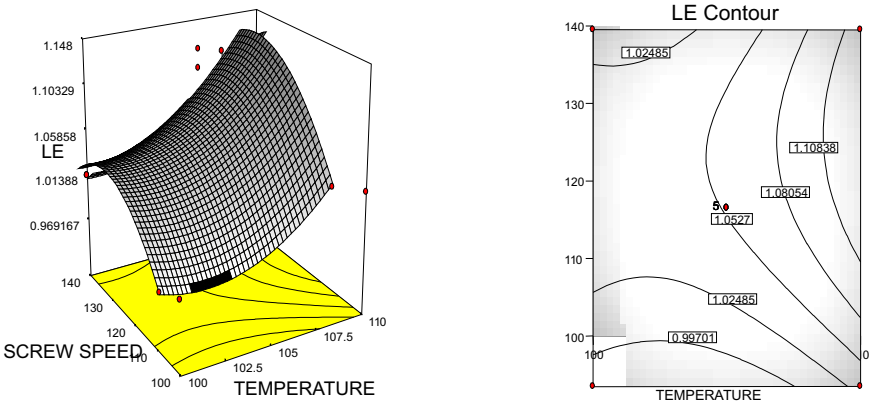

Figure 3. Response surface and contour plots of Lateral expansion as affected by screw speed and temperature at constant BSG level

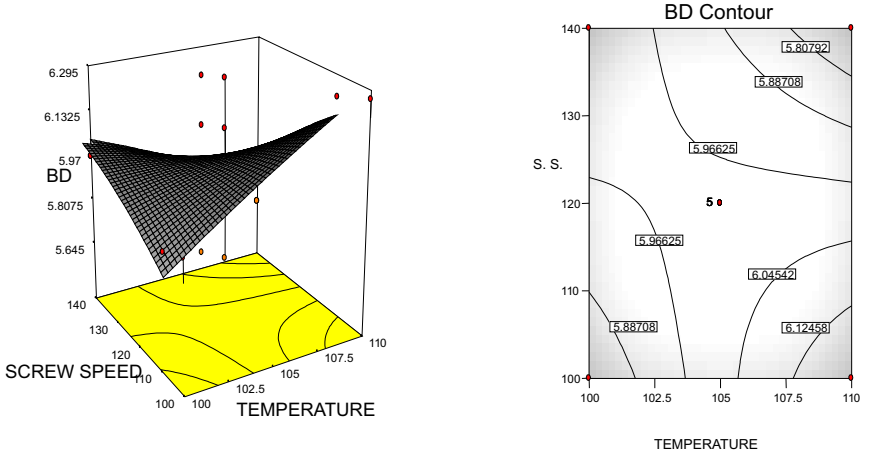

Figure 4. Response surface and contour plots of Bulk density as affected by screw speed and temperature at constant BSG level

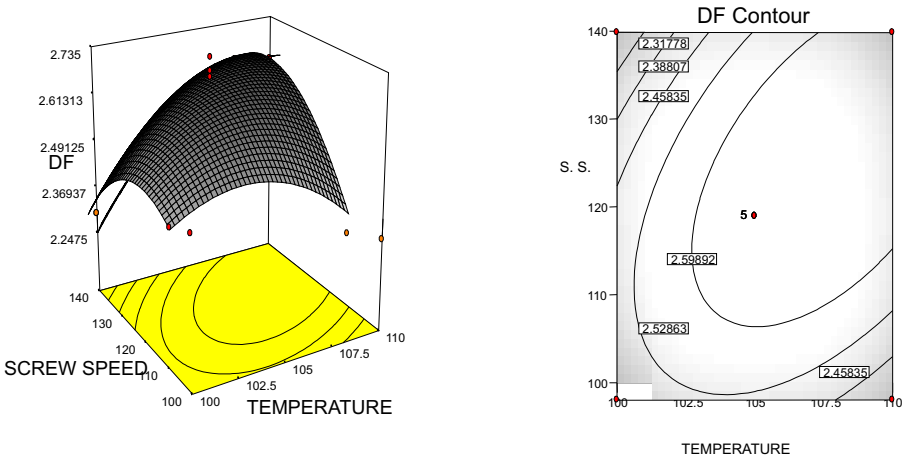

Figure 5. Response surface and contour plots of Dietary fibre as affected by screw speed and temperature at constant BSG level

Physicochemical properties of sweet potato flours as affected by processing methods in Sierra Leone

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Abstract

Roots of three different sweet potato varieties [Slipot II, Slipot III and a Local (Pa-Usman) variety] harvested 105 days after harvest, were processed into flour using three different processing methods (sweet potato flour from dry chips, flour from limed chips (lime/water ratio: 16/600) and that obtained from grating). The flours were evaluated for their physicochemical properties (swelling power, water absorption capacity, bulk density, angle of repose and moisture content). Results pointed out that sweet potato flours from all the sources considered (variety, processing methods and fertilizer treatment) produced angles of repose up to 35 degrees indicating free flow ability with some amount of cohesiveness. Angles of repose obtained from the respective sweet potato flours were greater compared to that of wheat flour (30.86°). Sweet potato flour obtained by the grating method yielded lower loose and tap bulk densities compared to those obtained from dry chips (method I and method II). The bulk densities (loose and tap) obtained from the respective sweet potato flours were low compared to wheat flour making sweet potato flour suitable for the formulation of high nutrient density weaning food. The slight difference between loose and tap bulk density also offer sweet potato flour a packaging advantage. Flours obtained from the improved varieties (Slipot II and Slipot III) swelled more than the local variety. Swelling powers and water absorption capacity of sweet potato flours obtained from the different processing methods and varieties varied significantly ($p < 0.05$). Moisture was significantly affected by the different sweet potato varieties. Also flour obtained by processing method I had moisture content significantly different from processing methods II and III. Sweet potato flours irrespective of variety and processing method, yielded moisture contents (average- l2.57%) lower than the normal (14%). This provides the flours an advantage with regards to their shelf life.

Keywords: Physico-chemical properties, processing method, variety, sweet potato flour

Introduction

Sweet potato is the second most important tuberous root crop in Sierra Leone after the root crop, cassava. It is usually grown throughout the year in the country for food and cash. Sweet potato is a highly nutritious vegetable containing high energy, dietary fiber, biologically active phytochemicals, vitamins and minerals which offer a great benefit for use as a functional food ingredient (Brinley *et al*., 2008). The storage roots are the most economically important part of the crop, although the leaves can also serve as a valuable source of vitamins and minerals. After harvest, the roots undergo rapid undesirable physiological changes if not properly cured. This problem therefore calls for elaborate processing to reduce high postharvest losses. The roots can be processed into a variety of products depending on local customs and preferences. Flour is one of the forms into which sweet potato roots can be processed to add value and increase its shelf life. Raised white breads, cakes and other flour derived products made from wheat flour have become increasingly popular in many tropical and sub-tropical countries, including Sierra Leone. Wheat is not grown in the country and must be imported, unfavorably altering the import export balance. Therefore, it would be worthwhile to develop considerable interest in the possibility of using locally produced sweet potato flour as a substitute for a portion of the wheat flour needed. Sweet potato flour can also be used as an ingredient in baby foods.

As the need for alternatives to wheat flour is gradually increasing in the sub region due to its high cost (importation costs) and other factors, there is the need for a thorough understanding of the properties (both physical and chemical) of these alternative sources of flour using wheat as a reference.

Physicochemical properties (solubility, swelling power, water absorption capacity, bulk density, angle of repose etc) are the intrinsic characteristics which may affect the behavior of

food systems during processing and storage. Adequate knowledge of these physicochemical properties indicates the usefulness and acceptability for industrial and consumption purpose. Studies on physicochemical properties of sweet potato flour are yet to be done in Sierra Leone with respect to varieties and processing methods. This study therefore provides relevant information in that light for the varieties and processing methods under consideration. Also, knowledge of these physical properties of sweet potato flours makes up an important and essential engineering data in the design of machines, processing and storage structures. The value of this basic information is not only important to engineers but also to processors, food scientists, crop breeders and other scientists that would exploit these properties and find new uses. Example, the bulk density is a major consideration in designing near-ambient aeration systems as these properties affect the resistance of air flow of the stored produce. In addition, bulk density is the basic parameter used to estimate the structural loads for storage structures. The angle of repose, according to Wouters and Geldart (1996) can provide the process engineer quickly with valuable information as it is taken as a predictor of possible flow difficulties in industrial applications. Barbosa-Canovas et al. (2005) also forwarded that the angle of repose can be used as a rough flowability indicator. In fact, they noted that it is the actual measurement applied in food industry quality control in order to evaluate flowability.

Aim and Objectives of the study

The ultimate aim of this study was to critically evaluate the physicochemical characteristics of sweet potato flours obtained from different processing methods and varieties.

The specific objectives included:

(i) To determine the swelling power and water absorption capacity of sweet potato flour obtained from each variety and processing method

(ii) To determine some physical properties (angle of repose, bulk density and moisture content) of respective flours with respect to variety and processing method.

(iii) To determine the chemical composition of the sweet potato flour among the different varieties and processing methods.

Materials and Methods

The sweet potatoes were harvested 105 days after planting at the Njala Agricultural Research Centre (NARC). Three methods of processing three (3) sweet potato varieties [*Slipot II, Slipot III* and *Local (Pa-Usman)*] into flour were considered.

These included

(i) Sweet potato flour from chips (PM1): this involved washing, peeling and slicing the roots into thin chips of roughly identical thickness. The chips were then sun dried and subsequently pounded into flour using a Hammer mill and a sieve (180mm mesh).

(ii) Sweet potato flour from chips using lime (PM2): this involved washing, peeling and slicing the roots into thin chips of roughly identical thickness. The chips were then immersed in lime solution (lime/water ratio: 16/600) for 35mins, sun dried and subsequently pounded into flour using the hammer mill and the sieve (180mm mesh).

(iii) Sweet potato flour from grating (PM3): this involved washing, peeling of the roots followed by grating using an engine operated grater. The grated mashes were then dewatered for about 24hours using the hydraulic press, sun dried and milled into flour.

Moisture Content

Moisture content (MC) was determined by drying five (5) grams of flour sample for four (4) hours in an electric oven at a temperature of 105^0C. The moisture contents expressed as a percentage by mass of the product was given by the following formula (Sanni *et al*.,2005):

$$MC_{wb}\% = [(M_0\ M_1)/M_0].100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where

M_0 = mass of flour before drying

M_1 = mass of the flour after drying

MC_{wb}% = moisture content % wet basis (w.b)

Angle of repose (θ)

Angle of repose was measured by the pouring method (Teunou *et al*., 1995). A known quantity (500g) of sweet potato flour was poured from a height of 30cm above a horizontal surface and allowed to flow through a conical funnel having a spout diameter of 2 cm onto the surface .The angle of repose was calculated from the base angle formed by the heap of flour using the following relationship (Sjollema, 1963):

$$\vartheta = tan^{-1}(2H/D) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where
H = height of the heap of flour
D = diameter of the heap of flour

Bulk Density
The bulk density was determined by the method described by Pordesomo *et al*., (2007). This method involves delivering sweet potato flour into a cylindrical container to full capacity from a height of 150 mm at a constant rate and then weighing the contents by means of a scale balance of 0.01 precision. No separate manual compaction of the flour was done. The volume of the container was estimated by filling the container with water and measuring it a 500 ml measuring cylinder. The loose (LP_b) and tap (TP_b) bulk densities of the flour samples were determined. The loose bulk densities of all the flour samples were determined by dividing the weight of the powder delivered freely by gravity into the cylinder by its volume whereas the tap bulk densities were calculated from the weight of powder contained in the cylinder after being hand tapped 100 times at roughly 60 taps/min. In both cases excess powder was scraped from the top of the fixed volume container by sliding a plastic straight edge across the container rim so that the material surface was flush with the container rim. Care was taken so as not to disturb or compact the settled powder. The bulk density (P_b) was calculated from the mass (M) in kilograms (kg) of the flours and the volume (V_c) in cubic meters (m^3) of the container from the relationship:

$$P_b = M/V_c \quad (3)$$

Swelling Power
The swelling power of the flour was evaluated using the technique prescribed by Tanya et al; (2006). This method involves adding a known volume (10ml) of warm water at a temperature of 60°C (granules of sweet potato flour swells at approximately 60°C; Aprianita et al; 2009) onto a known volume (4.5ml) of sweet potato flour and the mixture was mixed thoroughly with a glass rod for five (5) minutes, allowed to stand for 30minutes and then reading the increase in volume.

Water Absorption Capacity
A known volume (10ml) of distilled water was added to a known mass (2g) of sweet potato flour sample in a measuring cylinder (25ml). The mixture was mixed thoroughly using a glass stirrer for five (5) minutes and allowed to stand for 30 minutes. The volume of the supernatant was then recorded. The density of the water was assumed to be 1g/ml. The water absorbed was calculated as the difference between the initial volume of water used and the volume of the supernatant obtained (Sathe *et al*. 1982a). The mass of water absorbed by the flours was expressed as percentage on g/g dry weight basis.

Data Analyses
A three way analysis of variance was used to establish the level of significance among sweet potato varieties; fertilizer treatment and processing methods with respect to the various properties under study and means were compared using the Duncan's Multiple Range Test (DMRT) using a General Linear Model (SAS, 2001; version, 6.12). The level of significance was present at $p<0.05$. Results were expressed as the means ± standard deviation of three separate determinations. Correlation analyses were also done to establish the relationships among the different properties.

Results and Discussion
Results of the physical and chemical property measurements of the various sweet potato flours are presented in Tables 1 - 2.

Angle of Repose
Among the three sweet potato varieties, the local (Pa-Usman) variety produced the greatest angle of repose followed by the improved varieties Slipot II and Slipot III respectively. However, a significant difference ($p<0.05$) was observed between the improved Slipot III variety and the rest of the other two varieties.

For the different processing methods, method III (sweet potato flour processed by grating), produced the greatest angle of repose followed by method I (control) and method II (lime) respectively. These differences however, were significant ($p<0.05$). On the other hand, organic sweet potato flours also produced a greater value than the inorganic flours with respect to angle of repose (Table1).

Sweet potato flours from all the sources considered (variety, processing methods and fertilizer treatment) produced angles of repose up to 35 degrees which according to Carr (1976) indicate free flow ability with some amount of cohesiveness. This characterization method can provide a rough flow indication on small quantities

of flours that have not undergone any consolidation (Pordesimo *et al*; 2007).

Angles of repose obtained from the respective sweet potato flours (Table 1) were greater compared to that of wheat flour (30.86^{o}) (Pordesimo *et al*; 2007). However the difference was slight. This could be attributed to the difference in particle sizes as the particles of wheat flour are finer compared to that of the sweet potato flours considered.

Angle of repose differed significantly among all the interactions [variety*processing method, F=17.72, P=0.0001; variety*fertilizer treatment, F=5.72, P=0.0070; processing method*treatment F=37.16, P=0.0001; processing method* variety* fertilizer treatment F=23.50, P=0.0001].

Table 1. Flour Bulk Properties

Source	Bulk density (kg/m^3)		Angle of repose (deg)
	Loose	*Tap*	
Variety			
Slipot II	439.51^{ab}±26.39	543.08^{b}±31.27	34.38^{a}±2.63
Slipot III	448.02^{a}±22.33	567.59^{a}±23.20	33.96^{b}±1.41
Local (Pa-Usman)	437.28 ±26.35	545.37^{b}±41.36	34.61^{a}±1.04
Processing Method			
Method I (Control)	445.67^{a}±19.11	569.45^{a}±17.89	34.34^{b}±2.39
Method II (Lime)	452.89^{a}±18.67	567.90^{a}±20.83	33.25^{c}±1.17
Method III (Grating)	426.23^{b}±29.01	518.70 ±33.12	35.36^{a}±0.85
Fertilizer Treatment			
Organic (5 ton/ha)	443.86^{a}±26.42	552.18^{a}±27.42	35.18^{a}±1.82
Inorganic (120kg/ha)	439.34^{a}±23.91	551.85^{a}±40.15	33.45^{b}±1.34

Means with the same superscripts in each column are not significantly different (P<0.05 level DMRT).

Bulk Density

The loose bulk densities (LBD) of all the sweet potato flours considered (with respect to variety, processing methods and fertilizer treatment) ranged from 426.23 - 452.89 kg/m^3 while the tap bulk densities ranged from 518.70 - 567.90 kg/m^3. The improved Slipot III variety gave the highest value with respect to loose bulk density followed by Slipot II and the Local (Pa-Usman) variety (Table.1). However, the difference between the improved Slipot III variety and that of the local (PaUsman) variety was significant ($p<0.05$). Tap bulk densities also differed significantly between sweet potato flours with respect to the improved Slipot III and the local (Pa Usman) varieties.

With regard to the processing methods, method II (lime) produced the greatest loose bulk density followed by method I (control) and method III (grating) respectively. The difference between method III and the rest of the other two processing methods was significant ($p<0.05$). For tap bulk density on the other hand, sweet potato flours obtained from processing method I produced the greatest bulk density followed by method II and III respectively. Significant differences were also observed between the tap bulk density obtained from method III and the rest of the other processing methods.

The difference between the loose and the bulk densities of the respective sweet potato flours was slight, indicating that the volume of the flours in a package will not decrease excessively during storage or distribution. Loose and tap bulk densities correlates very strongly (Pearson

Correlation Coefficient: 0.92043; P = 0.0001) indicating a very high interdependence between the two properties. Studies conducted by Pordesimo et al; 2007 revealed that wheat flour produced loose and tap bulk densities of 549 kg/m^3 and 709 kg/m^3 respectively. These values are however high compared to those obtained by the sweet potato flours from all the sources considered thereby making sweet potato flour suitable for the formulation of high nutrient density weaning food (Desikachar, 1980).

Loose bulk density differs significantly between the interactions [variety* processing methods; df=4, F=7.25, P=0.0002; variety* processing methods*fertilizer treatment; df=4, F=9.28,P= 0.0001]

Significant differences were also observed among all the interactions for tap bulk density [variety*processing method; df=4, F=52.13, P=0.0001 ;fertilizer treatment*processing method; df=2,F=61.92,P=0.0001; variety*fertilizer treatment; df=2,F=10.47,P=0.0003;variety* fertilizer treatment*processing method; df=4,F=76.11, P=0.0001]

Swelling Power: The swelling powers of sweet potato flours at a temperature of 60^{o}C are shown in Table 2.The values ranged from 2.83ml to 5.37 ml. Among the varieties, Slipot III had the highest swelling power (5.37ml) followed by Slipot II and the Local (Pa-Usman) varieties with 3.91ml and 2.83ml respectively. The swelling powers of the respective sweet potato flours among all three varieties, were significantly different (*P<0.05*). Organic and inorganic sweet potato flours differ significantly with respect to swelling power with the organic flour swelling more than the inorganic flour (Table 2).

With regards to the processing methods, sweet potato flour processed from limed chips (Method2) had the highest swelling (4.49ml) followed by those processed by methods I (3.87ml) and III (3.75ml) respectively. This indicates that the immersion of the sweet potato chips in lime solution had an effect on the swelling power of the resulting flour. Differences in swelling powers among the different processing methods were significant (*P<0.05*).

There were also significant differences in swelling power among all interactions [variety*processing method df=4, F=75.42, P=0.0001; fertilizer treatment*processing method df=2, F=111.86, P=0.0001; variety*fertilizer treatment df=2 F= 463.03 =0.0001; variety* fertilizer treatment*processing method df=4, F=381.94, P=0.0001].

Moisture content (%) : The moisture contents of sweet potato flour produced from the respective sources are shown in Table 2. Moisture contents range from 11.66% - 12.92% dry basis. Slipot II appeared to have the overall highest moisture content (13.16%) than the rest of the other two varieties, Slipot III (12.92%) and the Local (Pa-Usman) (11.66%).the differences in moisture content among the different sweet potato varieties were significant (P<0.05).

With regards to the processing methods, a significant difference was observed between sweet potato flour processed by chipping (Method1: control) and the rest of the other two processing methods (Table 2). Sweet potato flour obtained by the grating method had the highest moisture content (12.83%) followed by method II (lime) and method III with moisture contents, 12.71% and 12.19% respectively.

The normal moisture content of flour is 14% (Roa and cock, 1973). Sweet potato flours obtained from all the different varieties and processing methods considered had moisture contents lower than this value. These values are also more or less equivalent to the moisture content obtained for wheat flour (11.98%)(Pordesimo et al; 2007); in fact sweet potato flour obtained from the local variety showed a moisture content value lower than that produced by wheat flour. Flours with moisture content above 14% are generally considered wet and normally have a shorter shelf life compared to those with a lower moisture level which are normally considered dry. At moisture content levels greater than 8%, the cereal powders which include wheat flour, are essentially considered wet while dairy powders (milk) with moisture less than 4% are relatively dry (Pordesimo et al; 2007).

Significant differences in moisture contents were also observed among all the interactions [variety*processing method df=4 F=31.96 P=0.0001; fertilizer treatment*processing method df=2 F=85.57 P=0.0001; variety*fertilizer treatment df=2 F=64.54 P=0.0001; variety* fertilizer treatment*processing method df=4 F=52.13 P=0.0001].

Table 2. Swelling Power, Moisture Contents and Water Absorption Capacity of sweet potato flours with respect to variety, processing method and fertilizer treatment

Source	Moisture Content (% dry basis)	Swelling Power (ml)	Water Absorption Capacity (%)
Variety			
Slipot II	$13.16^{a} \pm 1.21$	$5.37^{a} \pm 0.51$	$68.1^{a} \pm 0.53$
Slipot III	$12.92^{b} \pm 1.10$	$3.91^{b} \pm 1.07$	$50.5^{c} \pm 1.13$
Local (Pa-Usman)	$11.66^{c} \pm 1.01$	$2.83^{c} \pm 0.84$	$60.8^{b} \pm 1.67$
Processing Method			
Method I (Control)	$12.19^{b} \pm 1.25$	$3.87^{b} \pm 1.53$	$62.5^{b} \pm 1.16$
Method II (Lime)	$12.71^{a} \pm 1.37$	$4.49^{a} \pm 1.25$	$63.8^{a} \pm 0.96$
Method III (Grating)	$12.83^{a} \pm 1.18$	$3.75^{c} \pm 1.14$	$53.0^{c} \pm 1.73$
Fertilizer Treatment			
Organic (5ton/ha)	$12.27^{b} \pm 1.24$	$3.59^{b} \pm 1.49$	$60.8^{a} \pm 1.63$
Inorganic (120kg/ha)	$12.89^{a} \pm 1.25$	$4.48^{a} \pm 1.01$	$58.7^{b} \pm 1.11$

Means with the same superscripts in each column are not significantly different ($P<0.05$ level DMRT).
All values represent the mean of three replicates standard deviation.

Water Absorption Capacity: The water absorption capacity (WAC) of sweet potato flours (Table 2) showed that flour from the Slipot II variety had the highest value (68.1%) and flour from the variety Slipot III had the lowest value (50.5%).Among the three sweet potato varieties, significant differences were observed in all with respect to water absorption capacity.

Flours produced from the different processing methods also differ significantly with respect to their water absorption capacities. However, sweet potato flour produced by method 2 (lime) absorbs more water (63.8%) followed by method 1 (control) and method III (grating) with water absorption capacities of 63.8% and 62.5% respectively (Table2). These differences in water absorption were however significant ($p<0.05$).

The values obtained are lower than the values reported for taro flours - red 180%, white 166%, nive 150% (Tagodoe & Nip, 1994), soybean flour, 130% (Lin et al.,1974) and fluted pumpkin seed flour, 85% (Fagbemi & Oshodi,1991) but higher than those reported for sweet potato flour, red 24%, white 26% (Osundahunsi et al., 2003). The differences between the sweet potato flours studied in this piece of work and that studied by Osundahunsi et al., (2003) could be due to genetic and agro-ecological variation.

There were significant differences among all interactions [variety*processing method df=4, F=110.06, P=0.0001; fertilizer treatment*processing method df= 2, F=1150.40 P=0.0001; variety*fertilizer treatment df=2, F=163.11, P=0.0001; variety*fertilizer treatment*processing method df=4, F=538.97, P= 0.0001].

Conclusion

Sweet potato flour obtained from the improved Slipot III variety had a significantly lower angle of repose compared to the other two varieties, revealing that it flows more freely than the others. Contrastingly, angle of repose differed significantly among sweet potato flours from all the processing methods. However, sweet potato flour derived from processing method II (lime) had the lowest angle of repose among the three indicating a greater flowability.

Sweet potato flours from all the sources considered (variety, processing methods and

fertilizer treatment) produced angles of repose up to 35 degrees which indicate free flow ability with some amount of cohesiveness. Angles of repose obtained from the respective sweet potato flours (Table 1) were greater compared to that of wheat flour (30.86^{o}) which could be attributed to the difference in particle sizes as the particles of wheat flour are finer compared to that of the sweet potato flours considered.

Varietal differences had little effect on both the loose and tap bulk densities of sweet potato flour. On the other hand, processing methods had an effect on both loose and tap bulk densities. Sweet potato flour obtained by the grating method yielded lower loose and tap bulk densities compared to those obtained from dry chips (method I and method II). The bulk densities (loose and tap) obtained from the respective sweet potato flours were low compared to wheat flour making sweet potato flour suitable for the formulation of high nutrient density weaning food. The slight difference between loose and tap bulk density also offer sweet potato flour a packaging advantage.

Sweet potato variety had some effects on the swelling ability of the derived flour. Flours obtained from the improved varieties (Slipot II and Slipot III) swelled more than the local variety. Similarly, the swelling powers of sweet potato flours obtained from the different processing methods varied significantly indicating that this property is affected by processing method. Moisture was significantly affected by the different sweet potato varieties. Also flour obtained by processing method I had moisture content significantly different from processing methods II and III. However, all the sweet potato flours irrespective of variety and processing method, yielded moisture contents lower than the normal (14%). This provides sweet potato flour an advantage with regards to its shelf life.

Water absorption capacity was influenced by sweet potato variety as significant differences ($p<0.05$) were observed among all the varieties under study. The different processing methods also influenced the water absorption capacities of the derived flours.

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