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Original Research Article

Quality of cassava flour as affected by age at harvest, cropping system and variety

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Abstract

Pre-harvest operations affect the quality of food products. This study evaluated the impact of age at harvest (AH), cropping system (CS) and variety on the chemical and functional properties of high quality cassava flour (HQCF). Two white-fleshed (TMS 30572 and TMS 98/0505) and three yellow-fleshed (TMS 97/JW2, TMS 01/1371 and TMS 01/1368) cassava varieties planted either as sole crop or intercropped with maize were harvested at 12, 15 and 18 months after planting, and processed into HQCF. Chemical composition (proximate, mineral), physico-chemical properties (pH, total titratable acidity and colour) and functional properties (bulk density, water absorption index, dispersibility, swelling power, solubility index and pasting properties) of HQCF were determined. Data obtained were analysed using general linear model (GLM). AH had a significant ($P < 0.05$) effect on proximate and mineral composition, functional and physico-chemical properties, peak and breakdown viscosities, and peak time of HQCF. CS significantly ($P < 0.05$) affected the crude fibre, fat, bulk density, swelling power, mineral composition, and physico-chemical properties (except L* and b*) of HQCF. Variety significantly ($P < 0.05$) affected the proximate (except moisture) and mineral composition, functional properties, and breakdown viscosity of HQCF. The interactive effect of AH, CS and variety was significant ($P < 0.05$) on fat, dispersibility, mineral composition, and physico-chemical properties. In terms of carbohydrate content, it is desirable to harvest cassava at 12 months after planting, with TMS 98/0505 being the choice variety. Recommendation of the desirable AH, CS and variety will vary according to the desired quality of the end-products. Age at harvest is the most important single factor affecting the proximate composition and functional properties of HQCF.

Keywords: Agricultural practices; cassava products; tropical root; functional properties; proximate composition

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is second after rice in importance as a source of carbohydrate in developing and tropical countries, and the fifth most important staple crop globally (Nweke et al., 2002; Beechoff, 2017). Cassava is a major player in the economy of many tropical countries, Nigeria inclusive. In Nigeria, cassava is often grown either as an intercrop with maize or sole crop on subsistence farms (Burns et al., 2010). Cassava intercropping is economical since the relative yield total (RYT) or land equivalent ratio (LER) is usually more than 1 (Kuper, 2017). RYT or LER expresses the sum of the relative yields of all crops when grown together compared to summed yields when grown separately. Due to its rapid post-harvest physiological deterioration and inconsistencies in household needs and market price, farmers leave cassava roots un-harvested for different periods of time (FAO, 2006; Saravan et al., 2016).

Development of high quality cassava flour (HQCF) has paved way for industrial utilization of cassava in Nigeria (Sanni et al., 2009). HQCF is used either alone or as a composite in snacks and complementary foods. Quality of HQCF is crucial in determining its utilisation either domestically or industrially. Factors such as cultivar, maturity level and pre- and post-harvest operations affect properties of cassava flour (Akingbala et al., 2009). The impact of exogenous factors such as cropping system on cassava flour is yet to receive desired attention from researchers. Age at harvest, cropping system and variety might influence the quality of cassava flour since these factors had been reported to affect quality of plant products (Safo-Kantanka and Owusu-Nipah, 1992; Bokanga, 1995; Cameron et al., 2008; Shittu et al., 2007; Wiesler et al., 2009). It was therefore hypothesised that there is no significant effect of age at harvest, cropping system and crop variety on the quality of cassava flour.

The literature is scanty on the comparative influence of age at harvest, cropping system, and variety on the quality of HQCF. Therefore the objective of this research report was to determine the effects of age at harvest (AH), cropping system and variety on the nutrient composition, physico-chemical, functional and pasting properties of high quality cassava flour..

MATERIALS AND METHODS

Materials

Low cyanide cassava varieties (TMS 30572, TMS 97/JW2, TMS 98/0505, TMS 01/1371 and TMS 01/1368) either planted as sole crop or intercropped with maize were harvested from the research farm of the Institute of Food Security, Environmental Resources and Agricultural Research, Federal University of Agriculture, Abeokuta. The roots were harvested at 12, 15 and 18 months after planting.

Preparation of HQCF

HQCF was prepared according to the method described by Dziedzoave et al. (2006). Cassava roots were sorted, peeled using sharp knife, washed and grated in a locally fabricated machine. Cassava mash was dewatered in a clean porous bag, using a manual screw press. The pressing time was kept short for 2 h in order to avoid fermentation. The pressed cake was then reduced into fine grits in order to aid sifting and drying. Drying was achieved through the use of air cabinet dryer (Genlab drying cabinet, Model DC500; Cheshire) at a temperature of 60 °C overnight. The milling of cassava mash was done using Fritsch attrition milling machine (D-55743, Germany) in order to transform the dried grit into free flowing flour. Screening was done using 0.25 mm sieve.

Chemical Analyses

Determination of proximate composition

The proximate composition was determined according to the method outlined in AOAC (2005). Moisture was determined in an oven (Model: GP/100/CLAD/F/250/HYD, Merseyside) at a temperature of 105 °C until a constant weight was obtained; ash was determined by incinerating sample in a muffle furnace (Gallenkamp muffle furnace; REX-C900, England) at a temperature of 600 °C for 6 h. Protein was determined according to Kjeldhal method. The fat content was determined by Soxhlet extraction. Crude fibre was determined by boiling defatted sample with 100 ml TCA, followed by refluxing, washing with hot distilled water, drying at 100 °C and ashing in a muffle furnace. The total carbohydrate was determined by subtracting the sum of the percentage of moisture, fat, ash, crude fibre and protein content from 100.

Determination of mineral matter

Manganese, iron and magnesium contents were determined by atomic absorption spectrophotometry (Thermoscientific S- Series; S4AA System, China). On the other hand, sodium and potassium contents were determined using a Jenway digital flame photometer (PFP7 Model).

Determination of functional properties

Determination of water absorption index (WAI)

Water absorption index was determined by the method described by Awoyale et al. (2015). About 1.25 g of sample was suspended in 15 mL distilled water at 30 °C in a centrifuge tube and centrifuged (Gallenkamp Centrifuge 90-1, England) at 527 × g for 30 min. The supernatant was decanted and the weight of the sedimentwas noted. WAI was calculated as:

$$\%\ \text{WAI} = \frac{\text{weight of bound water (g)}}{\text{weight of sample (g)}} \times \frac{100}{1}$$

Determination of bulk density

The method described by Akpapunam and Markakis (1981) was used to determine the bulk density. Ten grams of sample was put into a 50 mL graduated measuring cylinder. The cylinder, with its content, was gently tapped on the bench top 10 times. The volume of the sample was recorded and bulk density was calculated as:

$$\text{Bulk density (g/ml or g/cm}^3\text{)} = \frac{\text{weight of sample}}{\text{volume of sample after tapping}}$$

Determination of dispersibility

This was determined by the method described by Kulkarni et al. (1991). Ten grams of sample was suspended in 100 mL of distilled water in a measuring cylinder. The mixture was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 100. The difference was reported as percentage dispersibility:

$$\text{Dispersibility (\%)} = 100 - \text{Volume of settled particle}$$

Swelling power (SP) and solubility index (SI)

The method of Leach et al. (1959) was used. One gram of sample was weighed into 100 mL conical flask, hydrated with 15 mL of distilled water and shaken for 5 min on a shaker (Orbital Shaker S01, Stuarts Scientific Co. Ltd, United Kingdom). The flask was then transferred to a vibrating water bath maintained at a temperature of 80–85 °C for 40 min. Thereafter, the content of the flask was carefully transferred into a centrifuge tube, with about 7.5 mL distilled water used for rinsing. Centrifugation was done in a Gallenkamp Centrifuge (90-1, England) at 1,207 ×*g* for 15 min. The supernatant was then decanted into a pre-weighed moisture can and dried at 100 °C to a constant weight. The weight of the sediment was noted, and the swelling power and solubility calculated as:

$$\text{Swelling power (g/g)} = \frac{\text{weight of sediment (g)}}{\text{sample weight (g)} - \text{weight of solution (g)}}$$

$$\text{\% Solubility index} = \frac{\text{weight of soluble (g)}}{\text{weight of sample (g)}} \times \frac{100}{1}$$

Determination of pasting properties

Rapid Visco Analyser or RVA (Tecmaster, Pertens Instruments, Australia) was used. This was done according to the description of Ohizua et al. (2017). Three grams of the flour sample were dispensed into the test canister and 25 mL distilled water added. On switching on the RVA, the sample information was input, and the pasting performance of the flour was automatically recorded. RVA curve obtained was evaluated for the peak viscosity, peak time, break down, minimum viscosity, setback and final viscosities and the final pasting temperature and time using the computer software.

Determination of physicochemical properties

Determination of pH

Ten grams of sample was dissolved in 100 mL of distilled water. The mixture was filtered using No. 1 Whatman filter paper. The pH meter was standardised with buffers of pH 4 and 8. The pH electrode was washed with distilled water and the electrode was placed in the filtrate. The electrode was allowed to stabilise for a few moments. The pH value of the filtrate was recorded (AOAC, 2005).

Determination of total titratable acidity (TTA)

Twenty five millilitres of filtrate as prepared for pH above was transferred into 125 mL conical flask. Two to three drops of phenolphthalein indicator were added to the conical flask containing the filtrate. The content of the conical flask was titrated with 0.1 M NaOH until indicator changed to pink and the volume recorded (AOAC, 2005).

Colour analysis

This was determined using a Chroma Meter (CR-410; Konica Minolta, INC, Japan). The instruction manual was followed in the determination. White calibration was done using the white calibration plate. Calibration and sample measurement were done at room temperature. For both the calibration plate and sample, the measuring head was placed vertically above the middle and the measurement button was pressed after the lamp indicated readiness. The resulting L*, +a*, −a*, +b, and −b* values refer to the lightness, redness, greenness, yellowness and blueness, respectively.

Data Analysis

Data were analysed using the General Linear Model on Statistical Analysis System.

RESULTS

Proximate composition

The effects of AH, CS and variety of cassava, and their interactive effects on the proximate composition of HQCF are presented in Table 1. AH had a significant ($P < 0.05$) effect on all the components of proximate composition of HQCF while CS had a significant ($P < 0.05$) effect on the crude fibre and crude fat contents of HQCF. Variety, on the other hand, significantly ($P < 0.05$) affected the ash, crude fibre, crude protein, crude fat and carbohydrate contents of HQCF. The interactive effect of AH and CS was significant on crude fibre, protein and crude fat, while that of AH and variety significantly ($P < 0.05$) affected ash and crude fat. The interactive effect of variety and CS was significant ($P < 0.05$) on the crude fibre and crude fat while AH, variety and CS only had significant ($P < 0.05$) effect on crude fat.

The ash content of the cassava varieties in decreasing order was TMS 01/1371 (1.5–4.3 %) > TMS 01/1368 (1.0–3.18 %) > TMS 98/0505 (1.0–1.93 %) > TMS 30572 (1.0–1.78 %) > TMS 97/JW2 (1.0–1.75 %). The crude fibre of HQCF ranged between 0.04 and 0.41 %. The range of values for crude fibre among the varieties in decreasing order: TMS 01/1371 (0.07–0.41 %) > TMS 01/1368 (0.13–0.29 %) > TMS 30572 (0.04–0.23 %) > TMS 98/0505 (0.06–0.22 %) > TMS 97/30572 (0.04–0.23 %). The protein content of HQCF ranged between 0.33 and 0.97 %. The protein content of HQCF which initially decreased at 15 months increased at 18 months. The crude fat content of HQCF ranged from 0.08 to 0.97 %. There was an increase in the fat content of HQCF as the AH increased. The carbohydrate content decreased with increase in AH. The carbohydrate contents varied among the varieties in the following decreasing order: TMS 98/0505 (87.97–94.0%) > TMS 97/JW2 (89.52–93.47%) > TMS 01/1368 (86.75–93.01%) > TMS 30572 (89.32–92.99%).

Mineral composition

The mineral composition (manganese, magnesium, iron, potassium and sodium) of HQCF was significantly ($P < 0.05$) affected by the main and interactive effects of AH, CS and variety (Table 2). The manganese, magnesium, iron, potassium and sodium contents

Table 1. Proximate composition of high quality cassava flour as affected by age at harvest, cropping system and variety of cassava roots

Age at harvest (AH)	Cassava variety	Cropping system (CS)	Moisture (%)	Ash (%)	Crude fibre (%)	Protein (%)	Crude fat (%)	CHO (%)
12 mo	TMS 30572	Intercropping	5.80	1.00	0.40	0.69	0.09	92.02
		Sole cropping	5.50	1.00	0.23	0.67	0.25	92.35
	TMS 97/JW2	Intercropping	5.40	1.50	0.11	0.44	0.08	93.47
		Sole cropping	5.90	1.50	0.16	0.41	0.19	91.84
	TMS 98/0505	Intercropping	5.10	1.50	0.22	0.54	0.10	92.54
		Sole cropping	3.60	1.50	0.20	0.60	0.10	94.00
	TMS 01/1371	Intercropping	8.30	1.75	0.10	0.43	0.18	89.24
		Sole cropping	4.30	2.00	0.41	0.77	0.08	92.44
	TMS 01/1368	Intercropping	6.30	1.50	0.13	0.46	0.14	91.47
		Sole cropping	4.90	1.75	0.29	0.57	0.15	92.34
15 mo	TMS 30572	Intercropping	5.10	1.25	0.09	0.46	0.11	92.99
		Sole cropping	6.20	1.00	0.04	0.41	0.56	91.79
	TMS 97/JW2	Intercropping	5.10	1.25	0.12	0.53	0.65	92.35
		Sole cropping	6.60	1.00	0.12	0.40	0.12	91.76
	TMS 98/0505	Intercropping	5.10	1.00	0.13	0.45	0.87	92.45
		Sole cropping	6.00	1.00	0.12	0.41	0.15	92.32
	TMS 01/1371	Intercropping	5.30	1.75	0.07	0.33	0.26	92.29
		Sole cropping	6.20	1.50	0.12	0.35	0.25	91.58
	TMS 01/1368	Intercropping	5.40	1.25	0.10	0.45	0.38	92.42
		Sole cropping	5.30	1.00	0.13	0.43	0.13	93.01
18 mo	TMS 30572	Intercropping	8.07	1.78	0.04	0.65	0.14	89.32
		Sole cropping	7.08	1.75	0.06	0.66	0.38	90.07
	TMS 97/JW2	Intercropping	7.65	1.68	0.13	0.68	0.34	89.52
		Sole cropping	8.15	1.75	0.12	0.55	0.97	88.46
	TMS 98/0505	Intercropping	7.75	1.53	0.12	0.52	0.28	89.80
		Sole cropping	9.16	1.93	0.06	0.36	0.52	87.97
	TMS 01/1371	Intercropping	7.41	4.30	0.15	0.74	0.36	87.04
		Sole cropping	8.43	3.08	0.28	0.33	0.77	87.11
	TMS 01/1368	Intercropping	8.44	3.18	0.21	0.97	0.45	86.75
		Sole cropping	8.47	2.78	0.11	0.56	0.13	87.95
		Range	5.40–9.16%	1.00–4.30%	0.04–0.41%	0.33–0.97%	0.08–0.97%	86.75–94.00%
		LSD	0.511	0.188	0.027	0.049	0.007	0.583
		Age	*	*	*	*	*	*
		CS	ns	ns	*	ns	*	ns
		Variety	ns	*	*	*	*	*
		Age*CS	ns	ns	*	*	*	ns
		Age*Variety	ns	*	ns	ns	*	*
		Variety*CS	ns	ns	*	ns	*	ns
		Age*Variety*CS	ns	ns	ns	ns	*	ns

* = significant ($P < 0.05$); ns = not significant ($P > 0.05$); LSD = Least Significant Difference; CHO = Carbohydrate

of HQCF ranged from 0.01 to 0.43 mg/kg, 4.51 to 22.80 mg/kg, 0.10 to 2.02 mg/kg, 0.06 to 95.66 mg/kg and 0.50 to 21.23 mg/kg, respectively. The manganese and magnesium contents of HQCF decreased while the potassium and sodium contents increased with increase in AH. Iron was not detected in HQCF prepared from most of the varieties until 18 months.

Physicochemical properties

Except for b* (degree of yellowness) values which were not significantly ($P > 0.05$) affected by CS, Table 3 shows that the main and interactive effects of AH, CS and variety exhibited significant ($P < 0.05$) effect on the physico-chemical properties {pH, TTA and a* (degree of redness). The pH ranged between 4.73

Table 2. Mineral composition of high quality cassava flour as affected by age at harvest, cropping system and variety of cassava roots

Age atharvest (AH)	Cassava variety	Cropping system (CS)	Manganese (mg/kg)	Magnesium (mg/kg)	Iron (mg/kg)	Potassium (mg/kg)	Sodium (mg/kg)
12 mo Months	TMS	Intercropping	2.00	213.30	ND	30.20	50.50
	30572	Sole cropping	4.10	208.20	ND	ND	66.50
	TMS	Intercropping	3.90	194.90	1.70	11.60	79.60
	97/JW2	Sole cropping	3.20	186.80	9.40	14.70	63.60
	TMS	Intercropping	2.40	221.30	1.00	20.40	56.90
	98/0505	Sole cropping	1.70	203.90	ND	5.70	72.20
	TMS	Intercropping	3.80	227.10	ND	20.90	114.10
	01/1371	Sole cropping	4.30	228.00	ND	2.70	95.50
	TMS	Intercropping	1.80	215.50	20.20	9.10	40.30
	01/1368	Sole cropping	2.00	222.00	14.40	23.40	58.60
15 mo Months	TMS	Intercropping	1.80	48.60	ND	293.20	31.70
	30572	Sole cropping	3.10	52.90	ND	269.80	9.80
	TMS	Intercropping	2.00	48.70	1.70	279.60	5.00
	97/JW2	Sole cropping	2.70	45.10	14.40	274.40	ND
	TMS	Intercropping	2.60	49.90	ND	272.70	31.60
	98/0505	Sole cropping	2.60	49.70	ND	300.20	34.60
	TMS	Intercropping	1.60	49.40	1.00	273.80	ND
	01/1371	Sole cropping	3.00	52.80	20.20	284.60	30.40
	TMS	Intercropping	2.20	49.20	9.40	274.00	14.60
	01/1368	Sole cropping	2.50	51.80	ND	262.70	22.90
18 mo Months	TMS	Intercropping	1.40	55.40	9.30	905.00	195.70
	30572	Sole cropping	0.40	52.60	1.60	0.60	176.30
	TMS	Intercropping	1.30	53.50	4.40	842.20	79.30
	97/JW2	Sole cropping	1.30	53.60	7.30	873.00	51.80
	TMS	Intercropping	0.70	48.70	11.20	785.50	59.90
	98/0505	Sole cropping	0.80	50.10	5.90	862.80	69.00
	TMS	Intercropping	1.40	56.90	6.60	956.60	140.20
	01/1371	Sole cropping	2.10	51.10	11.40	927.70	212.30
	TMS	Intercropping	1.00	55.00	5.40	911.80	153.40
	01/1368	Sole cropping	0.10	59.10	6.90	806.00	78.50
		Range	0.10 – 4.30	45.10 – 228.00	1.00 – 20.20	0.60 – 956.60	5.00 – 212.30
		LSD	0	0	0	0	0
		Age	*	*	*	*	*
		CS	*	*	*	*	*
		Variety	*	*	*	*	*
		Age*CP	*	*	*	*	*
		Age*Variety	*	*	*	*	*
		Variety*CS	*	*	*	*	*
		Age*Variety*CS	*	*	*	*	*

* = significant ($P < 0.05$); ns = not significant ($P > 0.05$); LSD = Least Significant Difference; ND = Not Detected

and 8.93 while TTA ranged from 0.03 to 0.45%. It was observed that the pH of HQCF prepared from intercropped and sole cropping systems ranged from acidic to alkaline regions. The pH of HQCF which initially dropped at 15 months increased at 18 months. The pH of HQCF decreased among the varieties in the following order: TMS 30572 (4.90–7.24) < TMS 01/1368 (4.82–8.46) < TMS 97/JW2 (4.98–8.51) < TMS 01/1371 (5.45–8.69) < TMS 98/0505 (4.73–8.93). L*(degree of lightness), a* and b*of HQCF ranged from 98.39–118.80, 0.24–2.39 and 9.90–28.03, respectively. The highest range of L* values of the HQCF samples was observed at 15 months AH, followed by 12 months AH. HQCF samples prepared from TMS 97/JW2 had

Table 3. The pH, TTA and colour of high quality cassava flour as affected by age at harvest, cropping system and variety of cassava roots

Age atharvest (AH)	Cassava variety	Cropping system (CS)	pH	TTA (%)	L*	a*	b*
12 mo	TMS	Intercropping	6.88	0.16	108.81	0.68	14.21
	30572	Sole cropping	7.24	0.09	113.48	0.62	14.51
	TMS	Intercropping	6.49	0.34	117.07	0.38	12.91
	97/JW2	Sole cropping	8.51	0.23	104.59	0.24	14.30
	TMS	Intercropping	8.04	0.38	106.75	0.43	13.10
	98/0505	Sole cropping	8.93	0.34	99.55	0.40	12.19
	TMS	Intercropping	8.15	0.04	108.22	0.53	16.83
	01/1371	Sole cropping	8.69	0.05	114.32	0.54	16.63
	TMS	Intercropping	6.37	0.20	107.56	0.84	14.19
	01/1368	Sole cropping	7.85	0.11	116.16	0.57	14.66
15 mo	TMS	Intercropping	4.90	0.18	112.61	0.76	10.91
	30572	Sole cropping	6.97	0.03	112.59	0.76	10.87
	TMS	Intercropping	5.35	0.21	116.45	1.25	13.92
	97/JW2	Sole cropping	4.98	0.18	118.80	1.13	11.48
	TMS	Intercropping	4.73	0.17	117.05	1.14	11.31
	98/0505	Sole cropping	7.01	0.05	113.26	0.87	12.36
	TMS	Intercropping	6.14	0.06	117.54	0.91	9.90
	01/1371	Sole cropping	7.09	0.03	114.32	1.89	13.73
	TMS	Intercropping	4.82	0.21	118.07	0.78	10.28
	01/1368	Sole cropping	6.27	0.07	118.53	1.30	11.61
18 mo	TMS	Intercropping	6.43	0.13	103.71	1.20	16.59
	30572	Sole cropping	6.50	0.18	105.25	1.06	15.18
	TMS	Intercropping	5.02	0.38	101.88	2.24	21.13
	97/JW2	Sole cropping	5.31	0.29	103.46	2.25	20.90
	TMS	Intercropping	4.79	0.45	100.45	0.56	13.68
	98/0505	Sole cropping	8.80	0.36	108.11	1.33	14.26
	TMS	Intercropping	5.45	0.41	98.75	2.39	28.03
	01/1371	Sole cropping	7.12	0.07	108.32	1.34	17.95
	TMS	Intercropping	8.46	0.04	98.39	1.42	16.52
	01/1368	Sole cropping	6.50	0.13	101.26	0.95	14.09
		Range	4.73–8.93	0.03–0.45	98.39–118.80	0.24–2.39	9.90–28.03
		LSD	0.0419	0.0419	0.2733	0.049	0.1652
		Age	*	*	*	*	*
		CS	*	*	*	*	ns
		Variety	*	*	*	*	*
		Age*CS	*	*	*	*	*
		Age*Variety	*	*	*	*	*
		Variety*CS	*	*	*	*	*
		Age*Variety*CS	*	*	*	*	*

* = significant ($P < 0.05$); ns = not significant ($P > 0.05$); LSD = Least Significant Difference

the highest lightness range. Flours obtained from sole cropping system were lighter than those from intercropping system.

Functional properties

The functional properties were significantly ($P < 0.05$) affected by the main and interactive effects of AH and variety (Table 4). The CS significantly $P < 0.05$) affected the bulk density and SP. The interactive effects of AH and CS significantly ($P < 0.05$) affected the WAI and dispersibility. The interactive effects of variety and CS, and AH, CS and variety had no significant ($P > 0.05$) effect on WAI and SI. AH and variety had the greatest impact on the functional properties. The values for

Table 4. Functional properties of high quality cassava flour as affected by age at harvest, cropping system and variety of cassava roots

Age at Harvest (AH)	Cassava variety	Cropping system (CS)	Water absorption index (%)	Bulk density (g/ml)	Dispersibility (%)	Swelling power (g/g)	Solubility index (%)
12 mo	TMS	Intercropping	120.80	0.67	66.50	7.10	31.50
	30572	Sole cropping	117.60	0.67	70.00	8.22	36.00
	TMS	Intercropping	130.40	0.65	67.50	8.08	24.00
	97/JW2	Sole cropping	115.20	0.65	71.00	8.48	32.00
	TMS	Intercropping	116.00	0.63	71.00	7.96	28.00
	98/0505	Sole cropping	116.80	0.74	71.50	9.47	28.00
	TMS	Intercropping	142.40	0.65	65.00	8.43	28.00
	01/1371	Sole cropping	140.80	0.71	59.00	7.09	33.00
	TMS	Intercropping	118.00	0.67	70.00	6.18	26.00
	01/1368	Sole cropping	123.60	0.63	69.00	8.50	23.50
15 mo	TMS	Intercropping	140.00	0.67	69.00	7.01	11.00
	30572	Sole cropping	130.80	0.70	65.00	7.99	16.00
	TMS	Intercropping	138.00	0.67	65.00	7.49	13.50
	97/JW2	Sole cropping	144.00	0.66	68.00	7.71	17.00
	TMS	Intercropping	158.40	0.65	66.00	8.41	17.50
	98/0505	Sole cropping	148.00	0.67	65.00	8.09	14.00
	TMS	Intercropping	141.20	0.67	59.50	7.70	15.50
	01/1371	Sole cropping	164.80	0.71	55.50	7.62	11.50
	TMS	Intercropping	140.80	0.67	69.00	7.17	9.50
	01/1368	Sole cropping	153.20	0.65	68.00	8.03	11.00
18 mo	TMS	Intercropping	136.00	0.66	62.00	6.12	1.00
	30572	Sole cropping	144.00	0.69	66.00	6.20	1.50
	TMS	Intercropping	124.00	0.70	65.50	6.76	3.50
	97/JW2	Sole cropping	136.00	0.71	64.50	6.10	4.00
	TMS	Intercropping	128.00	0.77	67.00	6.00	2.50
	98/0505	Sole cropping	136.00	0.73	61.00	6.74	1.00
	TMS	Intercropping	192.00	0.67	48.00	6.88	3.50
	01/1371	Sole cropping	188.00	0.67	56.00	7.67	3.00
	TMS	Intercropping	144.00	0.71	62.00	7.17	2.50
	01/1368	Sole cropping	172.00	0.71	56.50	6.93	2.00
		Range	115.20–192.00	0.63–0.77	48.00–71.50	6.00–9.47	1.00–36.00
		LSD	2.7366	0.0071	0.6192	0.2245	1.2231
		Age	*	*	*	*	*
		CS	ns	*	ns	*	Ns
		Variety	*	*	*	*	*
		Age*CS	*	ns	*	ns	Ns
		Age*Variety	*	*	*	*	*
		Variety*CS	ns	*	*	*	Ns
		Age*Variety*CS	ns	*	*	*	Ns

* = significant ($P < 0.05$); ns = not significant ($P > 0.05$); LSD = Least Significant Difference

WAI, bulk density, dispersibility, SP and SI of HQCF ranged from 115.20 to 192.00%, 0.63 to 0.77 g/ml, 48.00 to 71.50%, 6.00 to 9.47 g/g, and 1.00 to 36.00%, respectively. Generally, there was a gradual increase in WAI as the AH increased, with few exceptions. There was a gradual increase in the bulk density with increase in AH. The dispersibility decreased with increase in AH. There was a significant reduction in SI with increase in AH.

Pasting properties

The pasting properties of HQCF are presented in Table 5. Most of the pasting properties of HQCF were not significantly ($P < 0.05$) affected by AH, CS and

Table 5. Pasting properties of high quality cassava flour as affected by age at harvest, cropping system and variety of cassava roots

Age at harvest (AH)	Cassava variety	Cropping system (CS)	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak Time (min)	Pasting temperature (°C)
12 mo	TMS	Intercropping	245.29	127.63	117.67	165.79	38.17	4.10	75.13
	30572	Sole cropping	171.42	84.29	87.13	115.88	31.58	4.27	77.08
	TMS	Intercropping	279.83	152.71	127.13	210.13	57.42	4.33	75.98
	97/JW2	Sole cropping	285.42	129.71	155.71	179.04	49.33	4.17	77.55
	TMS	Intercropping	325.92	138.92	187.00	190.75	51.83	4.20	76.70
	98/0505	Sole cropping	338.75	146.25	192.50	191.29	45.04	4.44	78.75
	TMS	Intercropping	285.13	181.21	103.92	253.75	72.54	4.40	76.28
	01/1371	Sole cropping	289.08	143.96	145.13	194.13	50.17	3.93	74.65
	TMS	Intercropping	193.71	103.83	89.88	140.67	36.83	4.17	76.65
	01/1368	Sole cropping	336.50	134.88	201.63	186.17	51.29	3.97	75.88
15 mo	TMS	Intercropping	299.88	144.38	155.50	196.50	52.13	4.27	75.08
	30572	Sole cropping	283.33	129.54	153.79	192.96	63.42	4.33	76.30
	TMS	Intercropping	331.33	165.29	166.04	226.54	61.25	4.07	76.33
	97/JW2	Sole cropping	357.13	160.29	196.83	219.13	58.83	4.24	75.90
	TMS	Intercropping	278.75	135.88	142.88	194.21	58.33	4.27	76.70
	98/0505	Sole cropping	330.25	136.92	193.33	199.33	62.42	4.07	75.58
	TMS	Intercropping	330.29	159.21	171.08	226.08	66.88	4.37	75.13
	01/1371	Sole cropping	355.50	192.08	163.42	261.92	69.83	4.63	74.25
	TMS	Intercropping	404.42	181.88	222.54	240.04	58.17	4.04	75.88
	01/1368	Sole cropping	347.83	157.17	190.67	226.29	69.13	4.37	77.03
18 mo	TMS	Intercropping	266.21	124.58	141.63	180.17	55.58	4.34	75.50
	30572	Sole cropping	282.38	121.92	160.46	169.04	47.13	4.27	75.88
	TMS	Intercropping	283.96	141.21	142.75	194.96	53.75	4.37	77.88
	97/JW2	Sole cropping	297.50	156.33	141.17	207.75	51.42	4.40	76.63
	TMS	Intercropping	293.25	162.29	130.96	166.79	46.17	4.50	76.73
	98/0505	Sole cropping	322.54	130.08	192.46	196.42	66.33	4.60	77.08
	TMS	Intercropping	290.42	181.96	109.21	246.38	65.17	5.27	74.65
	01/1371	Sole cropping	318.21	244.92	73.29	328.88	83.96	5.54	76.68
	TMS	Intercropping	323.33	153.33	170.00	214.63	61.29	5.10	74.50
	01/1368	Sole cropping	353.25	215.79	137.46	277.71	61.92	5.17	76.25
		Range	171.42–404.42	84.29–244.92	73.29–222.54	115.88–328.88	31.58–83.96	3.93–5.54	74.25– 78.75
		LSD	14.768	10.434	11.017	14.345	4.0868	0.1319	1.8246
		Age	*	ns	*	ns	ns	*	ns
		CS	ns	ns	ns	ns	ns	Ns	ns
		Variety	ns	ns	*	ns	ns	Ns	ns
		Age*CS	ns	ns	ns	ns	ns	Ns	ns
		Age*Variety	ns	ns	ns	ns	ns	Ns	ns
		Variety*CS	ns	ns	ns	ns	ns	Ns	ns
		Age*Variety*CS	ns	ns	ns	ns	ns	Ns	ns

* = significant ($P < 0.05$); n s= not significant ($P > 0.05$); LSD = Least Significant Difference

variety. AH had significant ($P < 0.05$) effect on peak and breakdown viscosities, and peak time. Variety had significant ($P < 0.05$) effect on breakdown viscosity. The peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature of HQCF ranged between 171.42 and 404.42 RVU, 84.29 and 244.92 RVU, 73.29 and 222.54 RVU, 115.88 and 328.88 RVU, 31.58 and 83.96 RVU, 3.93 and 5.54 minutes, and 74.25 and 78.75 °C, respectively. The breakdown viscosity which initially increased at 15 months AH decreased at 18 months AH. The breakdown viscosity decreased among the varieties in the following order: TMS 30572 (87.13–155.5 RVU) < TMS 01/1371 (73.29–171.08 RVU) < TMS 98/0505 (130–193.33 RVU) < TMS 97/JW2 (127.13–196.83 RVU) < TMS 01/1368 (89.88–222.54 RVU). Hence, the preferred AH and variety in terms of breakdown viscosity were 15 months and TMS 01/1368, respectively. The peak time of the HQCF samples increased as AH increased: 3.97–4.44 min at 12 months AH, 4.04–4.63 min at 15 months AH and 4.27–5.54 min at 18 months AH. This trend was also observed for bulk density.

DISCUSSION

The moisture content range (5.40–9.16%) of HQCF is lower than earlier reports (Akingbala et al., 2009; Apea-Bah et al., 2011; Eleazu and Eleazu, 2012). The difference may be due to differences in drying methods and prevalent relative humidity during drying (Apea-Bah et al., 2011). Age at harvest and variety had been reported to affect the moisture content of HQCF (Apea-Bah et al., 2011; Eleazu and Eleazu, 2012). The moisture contents of all the HQCF samples were below the 10% maximum recommended by Standard Organisation of Nigeria (Sanni et al., 2005). The moisture content of a food is usually an indication of the likely keeping qualities of the product. The ash content which ranged between 1.00 and 4.30% is higher than in previous reports (Akingbala et al., 2009; and Eleazu and Eleazu, 2012). Except for two varieties (TMS 01/1371 and TMS 01/1368), the ash contents of HQCF samples were within the regulatory limit of 3% (Codex, 1989). The increase in ash contents as AH increased conforms to the report of Akingbala et al. (2009) but contradicts that of Apea-Bah et al.(2011). This observation may be due to varietal differences. Ash is often used to indicate the level of inorganic mineral elements in food. The crude fibre of the HQCF samples obtained in this study is lower than the range (0.77–2.62%) reported by Apea-Bah et al. (2011) for other varieties of cassava. The crude fibre decreased with increase in AH, contrary to the report of Akingbala et al. (2009), and this may be due to differences in CS and variety. Eleazu and Eleazu (2012) had earlier reported that variety had no significant ($p > 0.05$) effect on crude fibre of cassava flour. The values of crude fibre obtained in this study were below 2% upper limit specified for edible cassava flour (Sanni et al., 2005). The range of values obtained for the protein contents of HQCF is within the range reported by Maziya-Dixon et al. (2005), but lower than those reported by Akingbala et al. (2009) and Apea-Bah et al., (2011). Apea-Bah et al (2011) also reported that AH had a significant effect on the protein content of cassava flour, although they did not report any significant effect of variety on the protein content. The crude fat contents of the HQCF samples are higher than those reported by Akingbala et al. (2009) but lower than the values reported by Eleazu and Eleazu (2012), and this may be due to the influence of CS and variety. The carbohydrate content of HQCF which ranged from 86.75–94.0% shows that HQCF is a high energy food. In view of the fact that cassava is consumed mainly for its carbohydrate content, the most preferred AH is 12 months and the most preferred variety is TMS 98/0505. CS may not be an important factor to consider since its effect on the carbohydrate content was not significant.

According to US Institute of Medicine (2001 and 2005), the Recommended Dietary Allowances/Adequate Intakes of Mn, Mg, Fe, K and Na for adults are 2.3 mg/d, 320–420 mg/d, 8–18 mg/d, 4.7 g/d and 230–460 mg/d, respectively. The upper limits for Mn, Mg, Fe and Na for adults are 11 mg/d, 350 mg/d, 4.5 mg/d and 2.3 g/d, respectively. Thus, consumption of HQCF prepared from any of these five varieties and harvested at different CS and AH could significantly contribute to mineral intake of consumers. Manganese has been reported to be crucial in bone formation and metabolism of carbohydrate, fat and protein (NHMRC, 2006). Magnesium, an essential part of the enzyme systems, is important in the regulation of potassium fluxes and calcium metabolism (NHMRC, 2006). Iron serves as a regulator of some essential processes in the body, and its deficiency results in public health problem, especially in school children and women (Pereira et al., 2014). Potassium, the major intracellular cation in the body, is required for normal functioning of the cell (Institute of Medicine, 2005). Sodium and chlorine are important in the maintenance of extracellular volume and plasma osmolality (Institute of Medicine, 2005).

The pH is important in determining the end-use of HQCF, and cassava flour with pH ≤ 4 (indicating appreciable level of fermentation and hence starch breakdown) may not be suitable for baking since fermentation imparts characteristic aroma and sour taste to the flour (Apea-Bah et al., 2011). In terms of nearness to neutral pH, and hence suitability for baking purposes, 15 months is the desirable AH while TMS 30572 is the desired variety. The pH range is lower than those reported by Eleazu and Eleazu (2012), who also observed that pH of cassava flour was not affected by AH and variety. This difference may result from the processing methods used in obtaining the flour and CS. The acidity of the HQCF samples was within 1% standard limit (Sanni et al., 2005).

The colour of food materials has been reported to indicate the extent of deterioration or contamination (Bainbridge et al., 1996). The visual perception of the colour of the HQCF samples was white and non-objectionable and thus fulfilling the recommendations of Sanni et al. (2005) and Dziedzoave et al. (2006).

Water absorption index indicates the ability of flour to absorb water and swell for desirable consistency in food system (Induck et al., 2012). The higher the water absorption index the weaker the association of amylose-amylopectin and the higher the permeability of water into the granule (Olatunde et al., 2017). Thus, HQCF produced from older cassava roots will be desirable in the preparation of confectioneries and as thickeners. The range of values obtained for the bulk density of HQCF was slightly above the range reported by Eleazu et al. (2014). Bulk density is used in determining the packaging requirement of food materials (Iwe et al., 2016). Food materials with high bulk density have been reported to require high density packaging materials (Iwe et al., 2016). Low bulk density food requires less packaging requirement (Awoyale et al., 2015). Hence, HQCF samples from cassava roots harvested at 12 months will be desirable for low density packaging materials. Dispersibility measures the extent to which flour reconstitutes in water; higher value indicates better reconstitution in water (Adebowale et al., 2005), and less the energy needed for stirring to achieve uniform dispersibility and prevent lump formation in products such as complementary food (Awoyale et al., 2015). Hence, the preferred AH and variety from the standpoint of dispersibility is 12 months and TMS 98/0505, respectively. The swelling power of HQCF which decreased with increase in AH was lower than the values (10.48 to 12.04) reported by Eriksson (2013). This may mean that the digestibility of HQCF decreased as AH increased since high swelling power has been related to high digestibility and improved dietary properties of cassava starch (Abioye et al., 2017). In terms of swelling power, therefore, the preferred AH is 12 months while TMS 98/0505 with the highest range of values (6.00–9.47) is the preferred variety. Apea-Bah et al. (2011) reported that AH and variety had no significant effect on swelling power of cassava flour. This may be due to differences in cassava variety and cropping system. Solubility is an important parameter in baking since flour with a high solubility may give soggy and less cohesive dough (Apea-Bah et al., 2011). The solubility index obtained in this study was higher than that of Eriksson (2013).

Gelatinization and pasting are important phenomenon observed when starchy foods are heated in aqueous environment since they affect the utilisation and quality of foods (Wang et al., 2015). From the standpoint of AH, the peak viscosity varied from 171–336.5 RVU at 12 months, 283.33–347.83 RVU at 15 months, and 266.21–353.25 at 18 months. Thus, HQCF harvested at 18 months will perform better in products requiring high gel strength and elasticity. Peak viscosity reflects the ability of starch to swell freely before their physical breakdown (Sanni et al., 2004). High peak viscosity has been reported to be desirable in improving the texture of paste (Rosenthal et al., 1974). Peak viscosity also helps in indicating the viscous load likely to be encountered during mixing.

The hold period experienced during a typical pasting test is known as shear thinning, holding strength, hot paste viscosity, or trough. It is a measure of the ability of paste to withstand breakdown during cooling, and high values indicate little breakdown of starches. Final viscosity specifies the ability of food material to form a viscous paste or gel after cooking and cooling as well the resistance of the paste to shear force during stirring (Adebowale et al., 2005). The setback is a stage where retrogradation of starch molecules occurs and it has been related with texture of food; the higher the setback values the greater the tendency for retrogradation (Wang et al., 2015). The low setback viscosity observed in HQCF may indicate that the flours will exhibit a low tendency to undergo retrogradation. The peak time is a measure of the cooking time, or time to form paste.

Pasting temperature is an index of the minimum temperature required to cook a food sample. Food samples prepared from the HQCF samples will cook below the boiling point of water since the pasting temperatures of the flour samples were less than 100 °C. The pasting temperature range of HQCF increased at 15 months AH and then decreased at 18 months. A higher pasting temperature implies higher water binding capacity, higher gelatinization, and lower swelling property of starch due to a high degree of association between starch granules (Emiola and Delarosa, 1981; Numfor et al., 1996).

CONCLUSION

The study revealed that cassava variety TMS 98/0505 harvested at 12 and 15 months after planting had optimum carbohydrate content and quality of HQCF. For nearness to neutral pH, TMS 30572 variety harvested at 15 months after planting is the most suitable for baking purposes. Furthermore, HQCF obtained from sole cropping were lighter in colour than those from intercropping system.

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