Quality Assurance and Safety of Crops & Foods, 2015; 7 (5): 769-777

Impact of cassava flour properties on the sensory quality of composite white bread

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Received: 6 May 2014 / Accepted: 20 January 2015

RESEARCH ARTICLE

Abstract

The quality of composite baked products, which varies due to complex interaction of flour components, needs to be predictable for product optimisation purposes. This paper reports the impact of cassava flour (CF) from five cassava genotypes grown with or without fertiliser application on the quality of composite cassava-wheat bread. Composite breads were made with 10% of wheat flour substituted with CF. Sensory acceptability of the bread samples were determined based on crumb attributes (softness, elasticity, structure and colour), crust appearance, flavour and overall acceptability. Factorial analysis showed cassava genotype and fertiliser application during field cultivation significantly affected the crust appearance and crumb elasticity while their interactions affected all the sensory properties (P<0.01). Crumb softness influenced the overall acceptability of the composite bread most significantly. The partial least square (PLS) regression models for predicting sensory acceptability scores from CF properties explained about 98-100% of the variability. Based on the PLS regression, the study concluded that pH, cyanogenic potential (CNP), and least gelation concentration (LGC) of CF were the most influential quality criteria affecting the sensory acceptability of composite bread. Generally, CF with lower CNP, acidity, amylose, and higher LGC values will give more acceptable freshly baked composite bread.

Keywords: physicochemical properties, PLS regression, sensory acceptability

1. Introduction

Sensory perception is among the most important factors that determines the commercial success of existing and newly developed food products (Frewer, 1998). In addition, consumer's attitude which may be influenced by the amount of information available about the ingredient used in manufacturing it, cultural background, social status are among the important factors which determine food product acceptability (Frewer, 1998; Kihlberg *et al.*, 2005; Oths *et al.*, 2003). However, to ensure the commercial success of any product, one requirement is that the quality of the product must be highly predictable from all practical factors that interplay during the product's manufacture. The role played by raw materials or ingredient in determining product's quality is very critical. Therefore, for quality control purpose, the relationship between raw material and product qualities needs to be accurately predicted.

There is increasing interest in the use high quality cassava flour (HQCF) in food product development especially in countries where cassava production has comparative advantage over other staple crops. However, a lot of technical challenges especially those related to product formulation and process optimisation are still facing application of composite cassava wheat flour application in bakeries. Recent study by Shittu *et al.* (2008) has shown that the quality of flour from cassava varieties could have critical effects on the physical properties of freshly baked composite bread. Some studies have been conducted to relate wheat flour composition (Edwards *et al.*, 2007; Perez Borla *et al.*, 2004; Różyło and Laskowski, 2011) and dough properties (Dowell *et al.*, 2008; Janssen *et al.*, 1996; Scanlon *et al.*, 2000; Tronsomo *et al.*, 2003) to fresh loaf qualities as well as keeping qualities (Ito *et al.*, 2007). However, less emphasis has been paid to the quality of composite bread as influenced by composite flour or dough properties. Moreover, quantitative models for predicting sensory properties of white bread from 100% wheat or composite flour or dough properties are scarce. Since freshness of raw or processed food affects their acceptability, Heenan *et al.* (2008) studied the sensory qualities affecting the consumer's perception of freshness in white bread. They found that crumb appearance (porosity), odour (floury, toasted), flavour (oily) and aftertaste (sweet) are the most influential factor affecting consumer's perception of freshness. Also, Laureati *et al.* (2012) studied sensory factors affecting acceptability of gluten free bread. These authors concluded that the taste (sweetness), crumb texture (softness or elasticity), and crumb structure (porosity) of different gluten free and wheaten bread are important bread loaf properties that determine their sensory acceptability.

Some previous studies conducted on the use of composite cassava-wheat (CCW) flour for bread making purposes (Adeyemi and Idowu, 1990; Defloor *et al.*, 1993; Dhingra and Jood, 2004; Eggleston *et al.*, 1993; Hsu *et al.*, 2004; Khalil *et al.*, 2000; McWatters *et al.*, 2004) were devoted to determining the effect of cassava genotype and level of wheat flour substitution with cassava flour (CF) on their bread making quality. Similarly, Oladunmoye *et al.* (2010) reported effect of wheat flour substitution with either cowpea flour or cassava/maize flour blends on the physical, chemical and sensory qualities of composite bread samples. These authors reported varying extent of sensory quality impairment depending on the type of substitute flour, level of wheat flour substitution and in some cases, cassava genotypic effect. However, these authors did not establish any quantitative relationship between the flour and sensory properties as well as the acceptability of the composite bread.

The chemical composition of flours is a major factor that affects their utilisation. Their proximate solid components (carbohydrate, protein, fat and ash) are known to vary based on biological origin and some agronomic as well as processing factors. The polymeric (carbohydrate and protein) content of flour are the most important for their bakery application (Goesaert *et al.*, 2005). Flours from cereals (such as wheat) are known to have higher protein content than those from roots and tubers such as cassava and yam. In addition to polymer composition, their functionality as determined by the quality and distribution of the polymers is also important. The protein and starch qualities that differ in wheat flour have been shown to determine bake quality. The gluten forming protein of wheat determines the physical and sensorial textural quality of bread but it is not similarly important in other baked goods. Other important carbohydrate components that determine the quality wheat-based bakery products are the starch and fibre contents. Detailed functions of these components in bakery product manufacture have been presented elsewhere (Cauvain and Young, 2006; Dobraszczyk and Dendy, 2001; Pomeranz, 1998). However, in this study, the effect of wheat flour quality has been nullified because the same wheat flour was employed throughout. What varies here is the CF quality. The CF used here contains mainly starch (72.95-88.96%) with little amount of protein (0.96-2.09%). Therefore, the linear or non-linear additive effect of mixing the two types of flour is expected to present some technological effect on the final product quality.

The current study is a follow up of a previous study (Shittu *et al.*, 2008) in our laboratory. One of the objectives of this study was to test the hypothesis that nitrogen supplementation of soil will have significant effect on the sensory quality of CCW bread using flours derived from five cassava genotypes. The other major thrust of this paper was to gain insight into how CF properties could influence sensory preference of composite bread.

However, due to large number of flour properties considered here, partial least square (PLS) regression method was adopted for generating quantitative predictive equations since it is possible that some of the independent factors may be highly correlated with each other. PLS regression is useful to understand the underlying relationship between the variables. PLS regression technique is self-validating and it requires no extra effort to reducing the number of independent factors (as found with any data reduction methods) prior to quantitative model development (Abdi, 2003; Tobia, 2011).

Information from this study is expected to collectively guide bakers and millers on the quality control measures for procuring CF in addition to wheat flour meant for composite bread baking purposes.

2. Materials and methods

Materials

The main baking ingredients used are wheat flour (Honeywell Flour Mills, Lagos, Nigeria) and CF from five cassava genotypes (M98/0040, 82/0058, 92b/0061, 99/6012 and 98/0002) from IITA, Ibadan, Nigeria. Both flours have particle sizes <0.21 mm. The cassava plants were grown with (160 kg/ha NPK fertiliser) or without fertiliser. The level of fertiliser used is an average dosage applied by farmers in the country (Phillips *et al.*, 2004). The CFs used in this study are the same flours used in a previous study (Shittu *et al.*, 2008). The physical, chemical and functional properties of CFs are presented in Table 1.

Other baking ingredients used are Simas margarine (PT Intiboga Sejahtera, Jakarta, Indonesia), salt and sugar (Dangote Nigeria Plc., Lagos, Nigeria); Fermipan Baking yeast (DSM bakery ingredient, Dordrecht, the Netherlands), and Edlen Dough Conditioner (EDC 2000; Edlen International Inc., Atlanta, GA, USA).

Table 1. Physical, chemical and functional properties of the cassava flours used in the baking experiment (Shittu *et al.*, 2008).[1]

	82/00058		98/0002		92b/00061		M98/0040		99/6012		lsd (P<0.05)
	F	UF	F	UF	F	UF	F	UF	F	UF	
Peak viscosity (RVU)	163.25	275.04	351.92	322.63	224.96	216.42	264	227.21	277.83	306.46	27.07
Trough (RVU)	14.42	64.08	169.92	154.17	77.58	52.25	142.96	123.21	170.29	149.38	5.78
Breakdown viscosity (RVU)	148.84	210.96	182	168.46	147.38	164.17	121.08	104.3	107.54	157.09	5.55
Final viscosity (RVU)	24.71	80.58	232.46	225.92	112.13	73.67	189.54	166.67	227.55	208.83	6.52
Setback viscosity (RVU)	10.29	16.8	62.54	71.75	34.54	21.42	48.09	43.46	57.25	59.71	3.01
Peak time (min)	4.13	4.00	4.24	4.27	4.04	3.87	4.63	4.47	4.57	4.33	0.07
Pasting temperature (°C)	79.3	76.83	78.035	77.1	79.15	79.15	79.22	81.72	78.38	77.68	0.44
Diastatic activity (mg maltose)	148.0	198.0	62.5	75.5	101.0	125.0	125.0	176.0	22.5	93.0	13.0
Water absorption capacity (%)	201.67	21.71	195.11	16.55	172.68	18.97	170.5	17.83	161.97	17.75	7.79
Oil absorption capacity (%)	273.62	249.54	257.08	203.24	219.64	235.93	263.4	244.31	249.37	242.94	6.43
Swelling power (%)	10.26	13.46	14.78	15.13	12.53	12.8	10.63	12.05	10.81	14.09	0.9
Starch damage (%)	1.42	0.89	1.42	1.37	1.09	1.37	2.62	2.87	1.66	2.64	0.53
Least gelation concentration (%)	12	12	9	10	13	10	12	12	13	10	3
Protein (%)	1.73	1.48	1.38	4.3	1.29	1.04	2.09	1.93	0.96	1.20	0.42
Ash (%)	1.35	1.95	1.56	1.95	2.04	1.43	2.39	1.56	2.63	1.99	0.15
Sugar (%)	2.65	2.45	2.97	2.25	2.94	2.43	2.71	1.85	1.86	2.47	0.36
Starch (%)	82.26	88.46	88.96	90.15	75.67	80.84	84.66	76.52	85.23	86.7	5.17
Amylose (%)	19.74	18.82	18.73	18.42	23.5	23.38	23.47	23.81	20.81	23.29	0.12
Cyanogenic potential (mg/kg)	17.8	2.8	5.9	2.7	14.1	19.1	2.7	2.7	0.0	3.7	3.2
pH	6.03	5.99	5.94	5.98	5.36	5.34	5.23	5.67	5.28	5.9	0.02
Total titratable acidity (%)	0.34	0.38	0.32	0.32	0.25	0.36	0.36	0.47	0.36	0.41	0.09
Bulk density (g/cm^3)	0.34	0.34	0.32	0.25	0.39	0.36	0.32	0.48	0.28	0.41	0.025
L*	86.02	86.07	88.81	86.66	87.25	87.59	86.9	86.51	87.48	88.13	0.086
a*	1.23	1.37	0.81	1.34	1.20	0.50	1.06	1.78	1.13	0.66	0.127
b*	15.60	14.99	12.26	13.90	14.96	14.65	13.65	15.29	13.54	13.89	0.182

[1] F = fertilised; UF = unfertilised; lsd = least significant difference; RVU = rapid visco-analyser unit; L* = lightness; a* = redness; b* = yellowness.

Bread baking

The straight dough method described in Shittu *et al.* (2008) for CCW bread was used in bread dough preparation. The main ingredient of dough formulation used were wheat flour (90%) and CF (10%). The composition of other ingredients such as sugar (10%), salt (1%), yeast (1.5%), shortening (5%) and dough conditioner (0.3%) were based on the composite flour weight. The mixing was done manually for 15 min prior to kneading, which was also done manually for 3 to 5 min until smooth dough was obtained. The dough was divided into 200 g divisions, rolled and put immediately in the baking pan. Dough proofing was done in the pan at ambient conditions (29±2 °C, 79% RH) for 2 h. Baking was done with an electric oven (Gallenkamp, London, UK) at 180 °C for 25 min.

Sensory analysis

An untrained panellist group comprising of fifty members comprising of 30 females and 20 males among students and staff of the Federal University of Agriculture, Abeokuta, Nigeria participated in the sensory preference test. The ages of the participants ranged from 20-53 years with more than 80% of them having post-secondary school educational training. The participants were invited to the sensory analysis laboratory of the Department of Food Science and Technology after previous contact and consent to participate. They were also regular bread consumers, consuming at least 1 to 2 loaves of bread per week. Also, the participants had prior knowledge that the bread samples served were made from composite flour.

The sensory analysis was conducted in three sessions under fluorescent lightening condition that mimics daylight. Each panellist was served separately with a whole loaf for external quality assessment and a slice of about 4 cm thick from the same sample for crumb assessment from the same treatment. For each test session, three or four samples were presented randomly to a panellist simultaneously. The composite bread samples were coded and packaged in low density polyethylene bags before presenting them to the panellists not later than 4 h post-baking period. The panellists rated the bread samples for flavour, crumb structure, crumb colour, crumb elasticity, crust appearance, crumb softness and overall acceptability (OVAC) based on a nine point scale where 1 and 9 represent 'like extremely' and 'dislike extremely', respectively. The panellists were provided with potable water to rinse their mouth after each sample tasting for flavour assessment.

Data analyses

Means of the sensory data were separated using Duncan's multiple range test. Generalised linear model was generated to determine the main and interactive effects of the independent variables (genotype and fertiliser application) on the sensory attributes of the composite bread. SPSS 10.0 software package (SPSS Inc., Chicago, IL, USA) was employed in the data analysis. Partial least square regression of the acceptability scores for the composite bread against the CF properties was performed using XLSTAT 2011 statistical package (Addinsoft, New York, NY, USA).

3. Results and discussion

Sensory acceptability scores

Table 2 shows the sensory acceptability scores of the bread samples baked from different CF substituted as 10% of wheat flour. One way analysis of variance indicates that the sensory acceptability of the bread samples differed significantly ($P<0.05$). Within the same genotype of cassava there were no significant differences in the acceptability of the sensory attributes when fertilised samples were compared with the unfertilised samples except with 92b/0061. This same genotype gave the least and the most acceptable bread sample when the crop was fertilised and not fertilised, respectively. However, significant genotypic differences were found in the sensory quality attributes of the bread samples ($P<0.05$). The crusts of some bread samples from CF produced with or without fertiliser application had drier and rough surfaces (Figure 1). The most acceptable composite bread resulted from that containing CF made from unfertilised 92b/0061. The main reason for the observed difference may be due to genotypic difference. However, the cassava crops could have responded to soil fertility differently and in turn could have affected the flour properties. Hence, it is important to correlate the CF properties with the sensory scores of the bread samples.

Correlation of flour properties and sensory attributes

The term OVAC (or preference) often represents an average of consumer's preference for the food product based on certain perceivable product's attribute(s). Thus, understanding the factors influencing food product acceptability could give useful guide to food product developers on how best to optimise the product's quality.

To gain an insight into which attribute(s) could influence consumer acceptability of the product, Pearson's correlation coefficient between each sensory attribute and the OVAC determined. It was found that crumb softness had the highest correlation (0.872) with OVAC followed by either crumb elasticity or flavour (0.812) while crumb colour (CCOL) had the least value. It is worth noting that more

Table 2. Means (and standard deviations; n=50) of sensory parameters evaluated in composite bread from both fertilised and unfertilised cassava flour.[1]

Genotype	Treatment[2]	Crumb colour	Crumb softness	Crumb structure	Crumb elasticity	Flavour	Crust appearance	Overall acceptability
M98/0040	F	$3.5(0.9)^{abcd}$	$3.5(1.8)^{abcd}$	$3.4(1.4)^{b}$	$3.4(0.9)^{bcd}$	$3.0(1.0)^{ab}$	$3.7(1.7)^{cde}$	$3.5(1.8)^{bc}$
	UF	$3.7(1.4)^{cd}$	$4.0(1.5)^{cd}$	$3.9(1.6)^{bcd}$	$4.3(0.9)^{cde}$	$3.0(2.0)^{ab}$	$4.9(1.2)^{ef}$	$3.3(1.6)^{bc}$
99/6012	F	$4.5(1.1)^{d}$	$4.7(1.8)^{d}$	$5.2(1.2)^{d}$	$4.0(0.8)^{cd}$	$3.7(1.9)^{b}$	$5.1(1.2)^{f}$	$4.0(1.1)^{c}$
	UF	$3.6(1.2)^{bcd}$	$3.3(1.3)^{abcd}$	$3.8(0.8)^{bcs}$	$2.7(0.5)^{ab}$	$3.3(0.9)^{ab}$	$3.8(1.4)^{de}$	$3.3(1.5)^{bc}$
92b/0061	F	$3.9(1.3)^{cd}$	$4.3(1.4)^{cd}$	$4.9(2.0)^{cd}$	$4.4(0.8)^{de}$	$3.2(1.8)^{ab}$	$4.9(1.2)^{ef}$	$4.3(1.3)^{c}$
	UF	$2.4(1.1)^{ab}$	$2.1(0.6)^{a}$	$1.9(0.7)^{a}$	$1.6(1.2)^{a}$	$2.3(0.5)^{a}$	$1.3(1.2)^{a}$	$2.2(1.0)^{a}$
82/0058	F	$2.3(1.0)^{a}$	$2.9(2.2)^{abc}$	$4.1(1.2)^{bcd}$	$3.2(0.8)^{bdc}$	$2.8(0.9)^{ab}$	$2.5(1.0)^{abc}$	$3.5(1.7)^{bc}$
	UF	$3.2(1.0)^{abc}$	$3.0(0.8)^{abc}$	$3.4(1.4)^{b}$	$3.5(1.0)^{a}$	$3.2(1.2)^{ab}$	$3.6(0.9)^{bcd}$	$3.4(0.7)^{bc}$
98/0002	F	$3.3(0.7)^{abcd}$	$2.5(1.6)^{ab}$	$3.7(0.9)^{bc}$	$3.1(1.2)^{bc}$	$2.5(0.7)^{abcd}$	$3.3(1.1)^{bcd}$	$2.6(1.2)^{ab}$
	UF	$2.4(1.5)^{ab}$	$3.9(0.8)^{bcd}$	$3.2(0.8)^{b}$	$3.6(1.4)^{cde}$	$3.6(1.4)^{b}$	$2.4(1.0)^{ab}$	$3.7(1.8)^{bc}$

[1] 1 = like extremely; 9 = dislike extremely; mean values followed by the same superscript letter are not significantly different at 95% confidence limit.
[2] F = with application of nitrogen fertiliser; UF = without application of nitrogen fertiliser.

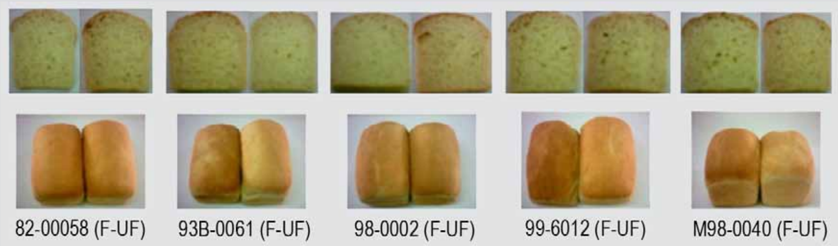

Figure 1. The physical appearance of the crumb and top crust of the composite cassava-wheat bread samples (F = fertilised cassava; UF = unfertilised cassava).

internal textural attributes showed greater correlations with the OVAC than others. The degree of correlation observed is as follows: crumb softness > crumb elasticity and flavour > crumb structure > crust appearance > crumb colour.

Factorial analysis of sensory properties

The analysis of variance results (Table 3) indicate that the CCOL, crumb elasticity and the crust appearance were influenced by cassava variety as previously observed by Eggleston *et al.* (1983) on CCW bread from different cassava clones. The main effect of fertiliser application was significant only on the crumb elasticity and crust appearance. The interaction of the independent factors also significantly affected all the sensory attributes except crumb elasticity. The significant interactive effect of the independent factors on the sensory properties might be due to the earlier observed compositional and functional differences of the CFs.

Prediction of sensory properties of composite bread from cassava flour properties

The combined weight plot (Figure 2) indicates that least gelation concentration (LGC), ash and protein contents, bulk density, oil absorption capacity and pH correlated positively whereas the cyanogenic potential (CNP), starch content, swelling power and diastatic activity had negative correlations with the sensory preference scores. A closer look at the plot indicates that positive correlations exist between LGC, protein, ash, bulk density of CF and acceptability scores of the composite bread samples. The independent variables (X-variables) that had the greatest weights on the principal components 1 and 2 are LGC and CNP (Figure 2). Incidentally, these variables had the greatest positive and negative correlation, respectively, with the Y-variables (sensory acceptability scores).

Table 3. Summary of multiple analysis of variance (MANOVA) on the sensory acceptability of the composite cassava-wheat bread.

Factor	Acceptability for	Mean square	F-value	*P*-value
Genotype	crumb colour	5.19	3.869	0.006
	crumb softness	3.82	1.929	0.112
	crumb elasticity	6.99	4.452	0.002
	flavour	1.49	1.554	0.193
	crust appearance	11.58	6.769	<0.001
	overall acceptability	0.74	0.575	0.681
Fertiliser	crumb colour	4.83	3.180	0.078
	crumb softness	2.56	1.294	0.258
	crumb elasticity	17.64	11.276	0.001
	flavour	0.40	0.042	0.838
	crust appearance	12.25	7.142	0.009
	overall acceptability	0.00	3.109	0.081
Genotype × Fertiliser	crumb colour	4.69	3.081	0.020
	crumb softness	1.64	5.377	0.001
	crumb elasticity	3.82	2.439	0.053
	flavour	2.92	3.051	0.021
	crust appearance	19.55	11.447	<0.001
	overall acceptability	0.70	5.207	0.001

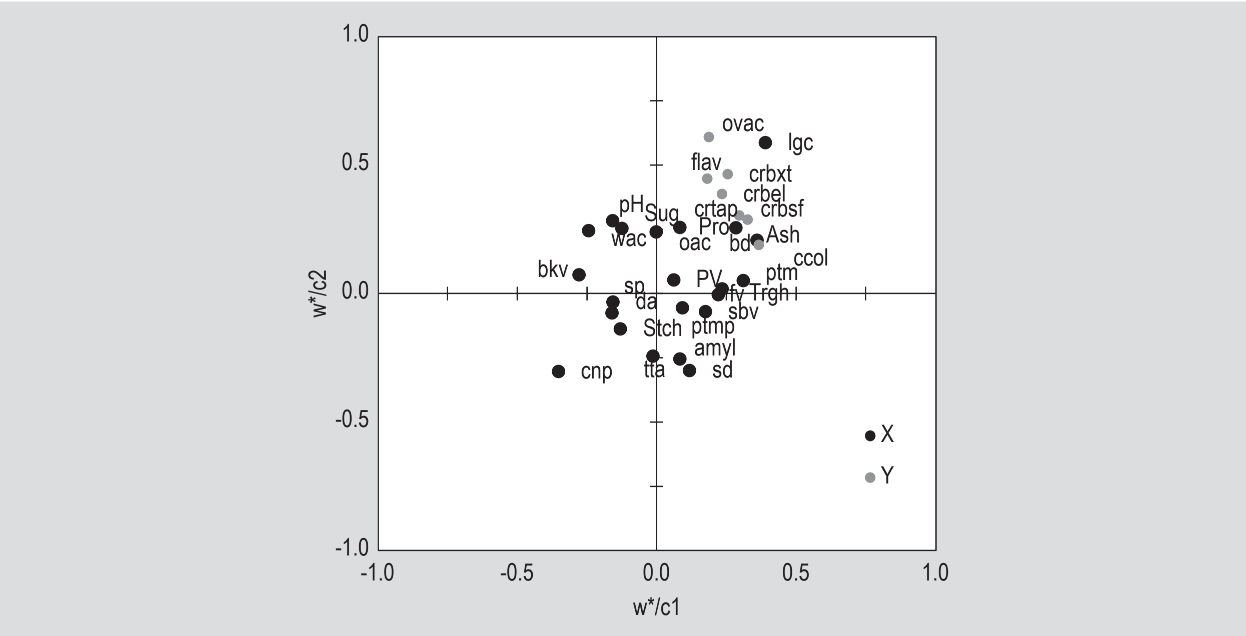

Figure 2. The combined partial least square plot of weights, w* and c for the first two components predicting the acceptability scores of sensory attributes (c) based on all flour properties (w*) (PV = peak viscosity (rapid visco-analyser unit; RVU); Trgh = trough (RVU); bkv = breakdown viscosity (RVU); fv = final viscosity (RVU); sbv = setback viscosity (RVU); ptm = peak time (min); ptmp = pasting temperature (°C); ash = ash content (%); da = diastatic activity (mg maltose); wac = water absorption capacity (%); sp = swelling power (%); sd = starch damage (%); LGC = least gelation concentration (%); amyl = amylose content (%); cnp = cyanogenic potential (mg/kg); Pro = protein content (%); Sug = sugar content (%); Stch = starch content (%); Crbxt = crumb structure; crbsf = crumb softness; crtap = crust appearance; ccol = crumb colour; crbel = crumb elasticity; flav = flavour; ovac = overall acceptability).

Table 4 shows the standardised coefficients of the CF properties on the sensory acceptability scores of bread samples. The relative values of the coefficient indicate the loading effect while the sign (- or +) indicate the direction of the influence i.e. decreasing or increasing the acceptability scores. LGC, CNP, pH and amylose content are the most influential on most of the sensory properties measured. Higher LGC and lower CNP of CF improved the acceptability scores generally. Similarly, increased pH had positive effect while amylose content had negative effects on bread acceptability. This finding is similar to what was reported by Semić *et al.* (2009) for white bread. The acidity effect was more pronounced on the crumb elasticity and structure as well as crust appearance than other properties. Standards Organization of Nigeria has stipulated that CF for baking should have pH range of 6-7. This is actually possible if cassava mash is not fermented during CF production thus making it qualify as HQCF. No study has so far reported correlation between CF pH and composite bread quality. This study has thus practically shown that CF of lower acidity (or unfermented CF) is more suitable for bread making purpose. High pH (lower acidity) has been reported to encourage necessary enzymatic process needed in the dough during fermentation for good crumb and crust formation (http://preview.tinyurl.com/owmm6l7) and improved sensory acceptability of white bread (Semić *et al.*, 2009).

The above result implies that CF with high gelling capacity (or low LGC) would result in composite bread of poor sensory quality. The most influenced sensory attribute by LGC is the crust appearance. The two underlying factors that could have influenced the crust appearance are the colour (degree of crust browning, colour uniformity) and surface finish (presence of cracks, dents, dryness). Water activity is major factor that influence the two browning reactions (Maillard and caramelisation) in baked goods apart from temperature and pH (Purlis and Salvadori, 2009). CF with lower LGC is expected to give the composite flour higher water absorption and by implication give higher water activity (a_w). The higher a_w could have led to reduced crust browning. This explains the significant positive correlation between LGC and crust appearance score (Pearson's correlation coefficient r=0.0.689, P<0.05). It is also interesting to note that from this study and our previous study (Shittu *et al.*, 2008), LGC of CF appears to be the commonest singular property influencing several physical and sensory property of composite bread loaf.

Least gelation concentration of flour is an important functional property which determines the minimum flour/

Table 4. Standardised regression coefficients showing the loading effect of flour properties on sensory properties of composite bread.[1]

Properties[2]	Crumb colour	Crumb softness	Crumb structure	Crumb elasticity	Flavour	Crust appearance	Overall acceptability
Protein (%)	-0.056	0.059	-0.100	0.199	-0.025	0.023	0.080
Ash (%)	**0.204**	0.057	0.060	0.073	0.065	0.151	0.080
Sugar (%)	-0.150	0.077	-0.025	0.113	0.021	-0.092	0.148
Starch (%)	-0.061	-0.176	-0.138	**-0.213**	-0.039	-0.137	-0.157
Amylose (%)	-0.023	**-0.236**	**-0.301**	**-0.299**	**-0.298**	-0.142	**-0.344**
Cyanogenic potential (mg/kg)	**-0.263**	**-0.272**	**-0.208**	**-0.370**	**-0.270**	**-0.338**	**-0.266**
pH	0.042	**0.288**	**0.476**	**0.286**	**0.380**	**0.205**	**0.327**
Total titratable acidity (%)	0.034	**-0.221**	-0.197	**-0.236**	-0.144	-0.038	**-0.329**
Diastatic activity (mg maltose)	0.002	-0.176	**-0.265**	-0.045	-0.180	-0.015	-0.194
Water absorption capacity (%)	-0.072	-0.099	-0.107	-0.020	-0.033	-0.054	-0.059
Swelling power	0.010	0.038	-0.048	0.051	0.066	0.040	-0.013
Starch damage (%)	-0.026	-0.093	-0.093	-0.161	-0.092	-0.064	-0.191
Least gelation concentration (%)	**0.275**	**0.317**	**0.386**	**0.420**	**0.255**	**0.364**	**0.395**
Bulk density(g/cm^3)	**0.207**	0.095	**0.255**	0.005	0.099	0.162	0.089
Oil absorption capacity (%)	-0.164	-0.075	-0.005	-0.096	-0.009	-0.157	-0.019
L*	-0.072	-0.153	**-0.241**	-0.215	-0.097	-0.160	-0.193
a*	0.072	**0.220**	0.180	**0.314**	0.126	**0.205**	**0.204**
b*	0.027	-0.061	0.061	-0.055	-0.057	0.022	-0.061
Peak viscosity (RVU)	0.039	0.074	-0.038	0.092	0.105	0.054	0.051
Trough (RVU)	0.069	0.151	0.061	0.140	0.137	0.098	0.111
Breakdown viscosity (RVU)	-0.049	-0.126	-0.160	-0.079	-0.054	-0.073	-0.098
Final viscosity (RVU)	0.067	0.169	0.092	0.148	0.154	0.103	0.128
Setback viscosity (RVU)	0.055	**0.209**	0.165	0.160	0.190	0.107	0.167
Peak time (min)	0.074	0.153	0.144	0.149	0.132	0.112	0.142
Pasting temperature (°C)	-0.050	0.089	-0.013	0.125	-0.041	0.019	0.044
Goodness of fit statistics							
r^2	0.997	0.991	0.987	1.000	1.000	0.985	0.962
Standard deviation	0.119	0.214	0.316	0.038	0.008	0.452	0.320
MSE	0.002	0.005	0.011	0.000	0.000	0.023	0.011
RMSE	0.040	0.071	0.105	0.013	0.003	0.151	0.107

[1] Values in bold fonts are the coefficient of independent variables having significant loading effects (P<0.05) on the sensory properties.

2 L* = lightness; a* = redness; b* = yellowness; r^2 = regression coefficient; MSE = mean square error; RMSE = root mean square error; RVU = rapid visco-analyser unit.

water ratio needed to produce gel from a cooked flour/water suspension. The gelation process is the main avenue for hydration of the protein/carbohydrate polymers system during baking. It could also affect the changes in a_w of dough during baking. Therefore, the varied gelling capacity of CF (or LGC) could have caused significant adjustment of the gelling properties of the composite flour the observed differences in sensory scores of the bread samples. It is noteworthy that our previous study on composite bread (Shittu *et al.*, 2008) similarly showed that LGC also had significant correlation with loaf weight and crumb colour properties.

The greatest effect of CF properties was reflected on the acceptability scores for crumb texture and structure. The degree of correlation between CF properties and sensory acceptability scores of the composite bread samples was high (regression coefficient r^2 ranged from 0.985 to 1.000). This indicates that the sensory acceptability of bread samples are highly predictable based on the cassava properties measured.

4. Conclusions

Varietal difference and nitrogen fertiliser application during cassava cultivation significantly affected the sensory quality of CCW bread. Crust appearance was the mostly influenced quality by these independent factors. Crumb softness influenced the acceptability of the bread samples. Highly significant PLS regression models for correlating the sensory data with the CF properties were obtained (r^2=0.985-1.00). At 10% level of wheat flour substitution used in this study for bread making, the principal CF properties that could be instrumental for optimising the sensory acceptability of CCW bread are the bulk density, ash, sugar, protein, CNP, pH, LGC and pasting peak time.

Acknowledgements

The International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, is gratefully acknowledged for granting a visiting research fellowship to the first author.

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