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Chemical and functional characteristics of some chemically peeled cassava cultivars' products

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Abstract

Cassava root is cultivated in tropical and subtropical regions of the world. The variability in weight, size and shape of cassava roots which are encased in peel made up of a periderm (corky) and cortex makes peeling a major problem especially in large scale processing. Information on chemical peeling of cassava and its effects on products are not common. This study investigated the effect of chemical peeling on the chemical and functional properties of some cassava products. Six cassava cultivars (two batches each) namely: TMS01/1371yr, TMS91/02324, TMS92/0326, TMS97/4763, TMS97/2205 and TMS30572 were immersed in 10% NaOH solution (1:2, w/v) at 96^{o}C for 5 minutes, batches were either further immersed in 3% citric acid solution (1:2, w/v) at ambient conditions for 1 minute or immersed in 15% NaCl solution (1:2, w/v) at 96^{o}C for 3 minutes. The softened peels of the pretreated cassava roots were washed off under running water with a hard brushing. Another batch was peeled using a stainless steel knife. Peeled roots were processed into flours and starches, and analysed for chemical and functional properties using standard methods. Chemical characteristics of cassava roots were protein (0.11-0.16%), fat (0.05-0.32%), ash (0.73-0.91%), fibre (0.24-0.29%), moisture (59.2-66.9%), sugar (0.28-0.50%) and starch (9.4-10.9 %). Protein content (1.15-2.05%) was highest in flours and starches made from cassava varieties peeled with NaOH/citric acid.. Water binding capacities (101.1-120.8%) was highest for NaOH/citric acid pretreated TMS92/0326. Swelling capacity ranged from 8.1 to 9.8% and solubility varied from 8.1 to 9.8% for the starches.

Keywords: Cassava Roots; Chemical Peeling; Chemical Characteristics; Functional Properties

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1. Introduction

Cassava is major source of nutrients and finance of up to 500 million people all over the world and there are many who engage in trading and processing of the both the product (Balagopalan, 2002). The importance of cassava in the lives of many Nigerians cannot be over emphasized. It supplies about 70% of the total caloric intake of more than half the population. As it comes first among root and tuber crops (Ikwelle et al., 2001). Besides being used as a direct source of food it is used as raw material in the manufacture of processed foods, animal feeds and industrial products (FAO, 1977; Plucknett et al., 1998; Adesina and Bolaji, 2013).

Nigerian cassava production is by far the largest in the world; a third more than production in Brazil and almost double the production of Indonesia and Thailand. Cassava production in other African countries, the Democratic Republic of the Congo, Ghana, Madagascar, Mozambique, Tanzania and Uganda appears small in comparison to Nigeria's substantial output (FAO, 2004b; Adebowale et al., 2012). It was projected that annual production by the end of 2010 would be 150 million tonnes (Wikipedia, 2014).

Over the past decade, extensive research and investment have taken place across Africa by diverse stakeholders in exploring and capitalizing on the potentials of cassava as a basic food product and a strategic commodity to be processed and refined for trade on regional, continental and international markets (Wambe et al., 2012). It is used in the production of a number of processed foods (*gari, tapioca*, cassava macaroni, sour flour, farihna, bread, *fufu, dumby, lafun*, etcetera), livestock feed and industrial raw materials such as liquid glucose and dextrin, fructose, maltose, malto-dextrin, modified starches, acetylated starches, cassava alcohol, citric acid, lactic acid, chips (FAO, 1998, Balagopalan, 2002). Cassava presently cuts across social strata and regions (rural and urban centres). It is grown by both the rich and the poor. In Nigeria, Cassava is a major staple food and industrial raw material, used in the production of many products. It was envisaged that about 150 million tonnes of cassava would required when 2006 would have gone by (FAO, 2004b). Cassava is the plant that gives the highest amount of energy (calories) per cultivated area when compared to other crops except for sugar cane. The roots are very rich in starch, is composed of calcium (50 mg/100g), phosphorous (40 mg/100g) and vitamin C (25 mg/100g). However, it is poor in protein and other nutrients (FAO, 2003). And an estimated over 70 million people obtain more than 500 calories per day from its consumption (CIAT, 2006). The nutritive value and content of cassava products depend on the cassava variety, the age of the tuber, and processing technology used in producing the food or feed (Akoroda and Ikpi, 2006). Investigations of five Asian cassava genotypes: Rayong 5, Kaesetsart 50 (KU50), Rayong 2, Hanatee and KMUL 36-YOO2 (YOO2), by Charles et al. (2005) showed that cassava contains 9.2–12.3% moisture, 1.2–1.8% crude protein, 0.1–0.8% crude lipid, 1.5–3.5% crude fibre, 1.3–2.8% ash, 80.1–86.3% carbohydrate. The fresh roots of cassava contain 30 to 40 percent dry matter and have a starch content that approximates 85 percent of the dry matter (Cock, 1982).

Cassava roots although very rich in energy contain very low amount of proteins, fats, minerals and vitamins which are needed fir proper functioning of the body. Due to this cassava has lower nutritional value than cereals, legumes, and even some other root and tuber crops such as yams. The root of cassava is made up of 64 to 72% carbohydrates, of which is made up of starch, mainly in the form of amylose and amylopectin.

The sweet varieties are made up of 17 per cent sucrose made up of small quantities of fructose and dextrose. The lipid content of cassava is only 0.5 per cent.

Cassava contains very low amount of proteins (1 to 2 per cent), and the amino acid profile of the cassava root is very low in some essential amino acids, especially, lysine, methionine and tryptophan. Cassava roots contain slightly more protein than the flesh. It is rich in calcium and vitamin C, but the thiamine, riboflavin, and niacin contents are not high. During processing high percentage of the nutrients are lost. It is necessary to consider these and choose a means of processing the will still result in nutrient retention (Okigbo, 1980; Emmanuel et al,

2012).

The varying shapes and sizes, length and diameter of the cassava tuber make it very difficult for peeling to be done as fast and efficiently as it should be. Peeling therefore is a major problem in the mechanization processing (Akintunde and Oyewale, 2005; Olukunle, 2005). Peeling operation by the use of simple machines has been done but many of them have been reported to be ineffective and slow. The peeling by use of perforated rotating drum (Akintunde and Oyewale, 2005) and by the use of a device with fast abrasive brushes (Olukunle, 2005) have also been reported. Lye peeling involves the use of approximately 10-15% sodium hydroxide or potassium hydroxide. The operation requires ample supply of water, lye and heat source. The product is passed through a heated lye solution, washed with water and typically dipped in acid to neutralize the remaining traces of lye (NFPA, 1996; Das and Barringer, 2006). According to Butler and Rivera, (2004), lye solutions at 100°C are often used in peeling soft fruits, at a concentration of between 0.5-10 percent. The fruits are usually submerged in the peeling agents for up to 4 minutes after which they are washed with jets of water and bathed in a solution of citric acid or ascorbic acid to neutralize any remaining caustic, transforming it into sodium. This principle has been applied to peeling of Yacon (*Smallanthus sonchifolus)*, trials were carried out using a range of concentrations of sodium hydroxide solution. This study, therefore, evaluated the effect of chemical peeling (NaOH, Citric acid, NaCl) treatments on some quality characteristics of fresh cassava roots, flour and starch from six varieties of cassava with the goal of minimizing the drudgery of peeling during cassava processing and possibly maximizing nutrients retention.

2. Materials and method

2.1. Processing

Six cassava roots cultivars: TMS01/1371yr, TMS91/02324, TMS92/0326, TMS97/4763, TMS97/2205 and TMS30572 were obtained from International Institute of Tropical Agriculture (IITA), Ibadan. Batch of the previously washed and drained cassava roots (2500 g) of the various cultivars were peeled with a knife according to the procedure described by FAO (1977) to obtain manually peeled cassava roots for analysis and processing.

The chemical cassava peeling was done using a modified method of Das and Barringer, (2006) in combination with Butler and Rivera, (2004) and ASABE, (2007). Previously washed and drained unpeeled cassava roots (1500 g) were carefully arranged in a stainless steel bucket and 10% NaOH solution at 96 ^oC was poured to cover the cassava completely. The bucket was then placed in a uniscope SM101 water bath at 96 ^oC with the shaker on and the set up was left for 5 minutes for the lye to react with the peel. At the end of five minutes, the roots were scooped out of the solution using a stainless steel spoon into another stainless steel bucket. Then 3% citric acid solution at ambient temperature was poured onto the cassava and left to stand for 1 minute or 15% NaCl solution at 96^oC was poured onto the cassava until they were completely immersed in the solution and the bucket with its content was once again put into the water bath at 96^oC and left for 3 minutes. The solutions were then decanted. The cassava roots were thoroughly washed under running tap water with continuous brushing until all the detachable peel under the condition was removed. The cassava root was rinsed with tap water and kept to drain off excess water, then weighed.

Peeled cassava roots (1500 g) were chipped using a sharp srainless steel knife. The wet chips were thinly spread on stainless steel trays and dried in a Uniscope SM 9053 laboratory oven at 65 ^oC. The chips yield was calculated with equation 1.

$$\% CY = \frac{W_{DC}}{W_{WC}} \times 100\% \qquad 1$$

Where

% CY= Percentage chips yield

W_{DC}=Weight of dried chips

W_{WC}=Weight of wet chips

Dried cassava chips (700 g a batch) were milled using Corona traditional corn mill REF 121 machine for a minimum of 6 milling stages to obtain a fine particle sized product (Figure 1). The milled cassava was then sieved to obtain fine flour.

Cassava roots

↓

Weighing

↓

Washing and Peeling

↓

Chip

↓

Dry (65^o C)

↓

Mill

↓

Sieve

↓

Flour

↓

Package

Figure 1. Cassava flour processing

Starch from the peeled roots was produced using the procedure represented in Figure 2 described by FAO (1979). Cassava roots (2000 g) were peeled (manually and chemically), and manually grated (rasped) with a stainless steel grater. The grated mash was mixed with water and sieved through a 100 µm sieve with lots of water until the filtrate becomes colourless.

Cassava roots

↓

Weighing

↓

Washing and Peeling

↓

Rasping, grating or Disintegration

↓

Screening

↓

Extraction

↓

Sedimentation

↓

Dewatering

↓

Drying

↓

Milling

↓

Packaging

Figure 2. Cassava starch processing

2.2. Determination of proximate composition

The percentage fibre content of the cassava products was determined using the method of Joslyn (1970). The procedures described by AOAC (2005) were used in determining the other proximate contents.

2.3. Determination of functional properties of the products

The bulk densities of the samples were determined using the procedure described by Wang and Kinsella (1976). Measuring cylinder (25 cm^3) was weighed and filled with 10 g of the sample. The cylinder and its content were gently tapped on a bench top 10 times and the volume occupied was noted. Bulk density was calculated using equation 2 .

$$\text{Bulk Density} = \frac{W(g)}{\text{V}\ (cm^3)} \qquad 2$$

Where

W=Weight of sample

V=volume of sample after fapping

The water binding capacity (WBC) was determined using the method described by Anderson (1982).

The solubility of the samples was determined using the method described by Onwuka et al. (2010). The test sanple (1 g) was poured into a 10 cm^3 measuring cylinder. Distilled water was added to it to make it up to the 10 cm^3 mark. The suspension was stirred for 1 min with a glass rod and allowed to stand for 1 h. The suspension was filtered with a whatman number 1 filter paper. The solubility in water was calculated by difference with equation 3

Calculation

$$\text{Solubility} = \frac{(W_d - W_t)}{W_s} \times 100\% \qquad 3$$

Where

W_s = weight of sample

W_t = Weight of filter paper + residue after drying,

W_d = weight of filter paper + sample

The swelling capacity of the samples was determined using the method of Talashi and Sieb (1988) while the sugar and starch contents of the samples were determined using the procedures described by Mcready (1970).

3. Results and discussion

Table 1 shows the chemical characteristics of the cassava cultivars roots. Protein content of the cassava roots varied from 0.11% to 0.43% and were not significantly different from one another (p>0.05). Result showed that TMS 01/1371yr had the highest fat content of 0.32% while the lowest fat (0.05%) was found in TMS 97/4763. The low fat content of the cassava roots is in agreement with reports of FAO (2000), which reported 0.2 to 0.5% fat and FAO (1977) which reported that cassava has 0.41% fat.

Table 1. Chemical Composition of the manually peeled fresh Cassava Cultivars

Cassava Variety	Protein content (%)	Fat content (%)	Ash content (%)	Fibre content (%)	Moisture content (%)	Sugar content (%)	Starch content (%)
TMS01/1371y	0.43^{a}	0.32^{a}	0.73^{a}	0.27^{a}	63.08^{c}	0.45^{a}	10.89^{b}
TMS30572	0.16^{a}	0.08^{a}	0.91^{a}	0.29^{b}	60.65^{b}	0.5a	10.56^{b}
TMS97/4763	0.16^{a}	0.05^{a}	0.81^{a}	0.26^{a}	65.26^{d}	0.48^{a}	10.51^{b}
TMS91/02324	0.15^{a}	0.06^{a}	0.82^{a}	0.34^{c}	59.22^{a}	0.28^{a}	9.19^{a}
TMS92/0326	0.11^{a}	0.06^{a}	0.89^{a}	0.24^{a}	66.88^{e}	0.32^{a}	9.4^{a}
TMS97/2205	0.15^{a}	0.06^{a}	0.82^{a}	0.29^{b}	63.37^{c}	0.44^{a}	10.74^{b}

Means with the same superscripts on the same column are not significantly different from one another (p>0.05)

WBC: Water Binding Capacity

The ash contents of the cassava roots varied from 0.73 to 0.91% for TMS 01/1371yr and TMS 30572 respectively. This is slightly different from the respective 0.54 and 0.3 to 0.5% ash content reported by FAO (1977 and 2000). This variation in the ash content could have been as a result of varietal differences and planting location variations (Nwokoro et al., 2006).

There was significant ($p<0.050$) variation among the fibre contents of the cassava varieties studied. Results showed that TMS 91/02324 had the highest (0.34%) fibre content which was significantly different from all other cultivars. These results differ from those reported by FAO (1977 and 2000) and PRCIS (2006) who reported fibre contents of 1.11, 0.8 and 1.1% respectively and 0.43% reported by FAO (1980).

The moisture content of the cassava roots varied from 59.22% in TMS 91/02324 to 66.88% in TMS 92/0326. The moisture contents of the various cultivars were all significantly different from one another ($p<0.05$). On the average the moisture content of the various cassava roots was 63.08% which is the range of moisture contents reported by PRCIS (2006), FAO (2000 and 1977) who reported that cassava root contains 62, 65 and 70.25% moisture, respectively.

The sugar content of the cassava cultivars ranged from 0.28 to 0.5% for TMS 91/02324 and TMS 30572 varieties respectively. The other cultivars, TMS 01/1371, TMS 97/4963, TMS 92/0326 and TMS 97/2205 had values of 0.45, 0.48, 0.32 and 0.44%, respectively. This is at variance with 5.13% reported by FAO (1977). The starch content of the cassava cultivars varied from 9.18 to 10.89% (TMS 91/02324 and TMS 01/1371 respectively). However, there was significant difference ($p<0.05$) between the starch contents of the cassava cultivars although some cultivars had similar values. The average starch content (10.22%) was lower than 21.45% reported by FAO (1977). The lower starch content could be due to the high moisture content of the cassava cultivars studied (wet basis) and due to the fact that cassava cultivars, the soil, geographical location affect the chemical and nutritional content of cassava roots (Nwaokoro et al., 2005).

Tables 2 and 3, show the effect of the peeling treatments on the chemical composition of the cassava cultivars' flour and starches respectively. The protein content of the cassava flours ranged from 1.15 to 2.05% for NaOH/NaCl peeled TMS 91/02324 and NaOH/citric acid peeled TMS 01/1371yr respectively. The result showed that peeling with NaOH/citric acid led to significant increase in the protein contents of the various flours when compared to flours from manually peeled cassava roots (1.49 to 2.05% for TMS 01/1371yr). Peeling with either NaOH/citric acid or NaOH/NaCl however, consistently resulted in improvements in protein contents of the starches in almost all the varieties. These slight increases in the protein contents of the chemically peeled cassava flour could have been because some of the peels of the cassava were still left after the peeling process especially for NaOH/citric acid peeled ones and proteins in them could have added up to the protein content of the flours, since cassava peels contain up to 8.2% proteins (Oboh, 2006).

The fat contents of the flours obtained from the different peeling treatments were significantly different from one another ($p<0.05$). Peeling with NaOH followed by NaCl led to the production of cassava flour with lower fat content for TMS 01/1371yr, TMS 30572 and TMS 97/2205 and higher fat content than manually peeled ones for TMS 92/0326, TMS 91/02324 and TMS 97/4763. Peeling with NaOH/Citric acid and NaOH/NaCl led to slight increase in the fat contents of TMS 91/02324 TMS 97/4763 and TMS 97/2205 when compared with manually peeled cassava starch.

Peeling with chemicals resulted in the lowering of the ash contents of cassava flours when compared to manually peeled flours. While the treatments led to slight increases in the ash contents of flours produced from NaOH/citric acid peeled TMS 92/0326, TMS 91/02324, TMS 30572 and TMS 97/2205. The peeling treatment, the cassava and the interaction between the two factors were significant (p<0.05).

Table 2. Effect of Peeling Treatments on the Chemical Composition of the Cassava Cultivars' Flour

Cassava Varieties	Peeling Treatment	Protein Content (%)	Fat Content (%)	Ash Content (%)	Fibre Content (%)	Moisture Content (%)	Sugar Content (%)	Starch Content (%)
TMS01/137'1yr	Manual peeling	1.49[d]	0.63[jk]	2.27[gh]	2.25[g]	8.48[i]	4.24[e]	80.34[a]
	NaOH/citric acid	2.05[k]	0.39[a]	2.10[de]	2.17[e]	7.95[c]	2.96[a]	83.33[i]
	NaOH/NaCl	1.17[a]	0.55[g]	1.23[a]	2.04[bc]	7.94[g]	4.27[e]	82.77[efg]
TMS92/0326	Manual peeling	1.63[e]	0.59[h]	2.22[fg]	2.02[b]	7.94[f]	3.61[bc]	82.49[de]
	NaOH/citric acid	1.70[fg]	0.44[b]	2.31[ji]	2.25[g]	7.47[f]	2.80[a]	83.07[ghi]
	NaOH/NaCl	1.20[ab]	0.61[lj]	1.93[a]	2.26[g]	7.45[f]	4.23[de]	81.23[b]
TMS30572	Manual peeling	1.83[i]	0.65[kl]	2.06[d]	2.16[e]	7.20[d]	3.00[a]	83.11[ghi]
	NaOH/citric acid	1.91j	0.50[ef]	2.21[fg]	2.09[d]	7.07[e]	3.57[bc]	82.65[def]
	NaOH/NaCl	1.31[c]	0.58[h]	1.30[a]	2.24[fg]	8.51[j]	4.13[cde]	78.93[c]
TMS91/02324	Manual peeling	1.64[ef]	0.50[de]	2.03[d]	2.07[bcd]	6.90[b]	3.61[bc]	83.91[j]
	NaOH/citric acid	1.71[gh]	0.47[cd]	2.10[de]	2.04[bc]	6.74[a]	3.68[bcd]	83.20[hi]
	NaOH/NaCl	1.15[a]	0.60[hi]	1.24[a]	2.05[bcd]	9.06[k]	3.73[cde]	81.99[c]
TMS97/4763	Manual peeling	1.82[i]	0.50[ef]	2.15[ef]	2.20[ef]	6.67[a]	2.87[a]	83.91[j]
	NaOH/citric acid	1.76[h]	0.49[de]	2.04[d]	2.04[d]	7.41[ef]	4.10[cde]	82.17[cd]
	NaOH/NaCl	1.23[b]	0.66[l]	1.68[b]	1.68[b]	7.65[g]	4.37[e]	81.71[c]

Means in the same column with the same superscripts are not significantly different from one another (p>0.0)

Peeling with the two chemicals resulted in reduction in the fibre contents of the flours. However, peeling with NaOH/NaCl resulted in cassava flour with higher fibre content than manually peeled flours for TMS 92/0326. It could also be due to the heat treatment used in the peeling which may have hydrolyzed some of the fibrous substances leading to lower fibre content. The peeling treatments effects were also significantly different from one another (p<0.05).

Table 3. Effect of Peeling Treatments on the Chemical Composition of the Cassava Cultivars' Starch

Cassava Varieties	Peeling Treatment	Protein Content (%)	Fat Content (%)	Ash Content (%)	Fibre Content (%)	Moisture Content (%)	Sugar Content (%)	Starch Content (%)
TMS01/137'1yr	Manual peeling	0.42^{b}	0.23^{de}	0.12^{a}	0.12^{ab}	6.76^{b}	3.25^{h}	89.09^{e}
	NaOH/citric acid	0.54^{h}	0.22^{abc}	0.12^{a}	0.13^{bc}	6.39^{a}	3.22^{h}	89.39^{c}
	NaOH/NaCl	0.47^{e}	0.26^{h}	0.31^{bc}	0.20^{e}	8.65^{c}	3.07^{fgh}	87.05^{a}
TMS92/0326	Manual peeling	0.48^{ef}	0.22^{abc}	0.13^{a}	0.13^{bc}	6.76^{b}	4.07^{k}	88.53^{e}
	NaOH/citric acid	0.51^{g}	0.21^{a}	0.12^{a}	0.12^{ab}	7.64^{e}	3.17^{gh}	88.86^{f}
	NaOH/NaCl	0.57^{i}	0.31^{i}	0.28^{bc}	0.22^{c}	8.65^{g}	2.34^{ab}	89.15^{g}
TMS30572	Manual peeling	0.42^{b}	0.27^{h}	0.13^{a}	0.12^{a}	6.10^{a}	2.92^{def}	90.06^{k}
	NaOH/citric acid	0.45^{c}	0.22^{abc}	0.13^{a}	0.12^{a}	6.65^{c}	4.59^{l}	87.92^{c}
	NaOH/NaCl	0.51^{g}	0.26^{h}	0.29^{bc}	0.19^{b}	7.77^{e}	2.65^{c}	88.35^{d}
TMS91/02324	Manual peeling	0.38^{a}	0.22^{abc}	0.12^{a}	0.11^{a}	6.42^{c}	2.47^{b}	90.30^{l}
	NaOH/citric acid	0.46^{d}	0.24^{ef}	0.13^{aa}	0.13^{bc}	7.05^{d}	3.45^{i}	88.57^{e}
	NaOH/NaCl	0.61^{k}	0.25^{fg}	0.27^{bc}	0.26^{c}	8.64^{g}	2.27^{a}	87.70^{b}
TMS97/4763	Manual peeling	0.43^{ab}	0.22^{ab}	0.12^{aa}	0.12^{a}	6.67^{c}	3.12^{gh}	89.33^{hi}
	NaOH/citric acid	0.65^{l}	0.26^{g}	0.24^{b}	0.13^{a}	6.63^{c}	3.64^{j}	88.31^{d}
	NaOH/NaCl	0.48^{ef}	0.25^{gh}	0.34^{c}	0.21^{b}	9.07^{h}	2.65^{c}	86.92^{a}
TMS97/2205	Manual peeling	0.50^{f}	0.22^{abc}	0.13^{a}	0.12^{a}	6.40^{b}	2.89^{def}	89.75^{j}
	NaOH/citric acid	0.48^{ef}	0.23^{bcd}	0.29^{bc}	0.13^{a}	8.38^{f}	3.00^{efg}	88.78^{f}
	NaOH/NaCl	0.59^{j}	0.30^{l}	0.26^{bc}	0.24^{b}	8.95^{h}	2.82^{cde}	86.86^{a}

Means in the same column with the same superscripts are not significantly different from one another ($p<0.05$)

Peeling with the chemicals led to the production of starches with generally higher fibre content than the manually peeled ones except for the starch produced from TMS 30572 and TMS 92/0326 peeled with NaOH/ Citric acid (0.12% fibre) for both treatments and the manually peeled one which had 0.13% fibre. A closer look at the fibre content of starch produced from the cassava samples peeled with NaOH/NaCl shows that they contain higher fibre content than those produced from both manually peeled and NaOH/ Citric acid peeled cassava. The statistical analysis showed that the cassava cultivar, the peeling treatment and the interation between them caused significant variation in the fibre content of the starches ($p<0.05$).

The moisture contents of the various cassava flours were between 8.51% and 6.74%. The moisture content of the flours were sinificantly different from one another ($p<0.05$). The test to know the effect the cassava cultivar, the peeling treatment, or their interactions had on the moiture content showed that they all had significant effects on the moisture contents of the flours ($p<0.05$).

Result shows that the solubility of the starches varied between 8.10 to 9.80%. Statistical analysis showed that there was no significant difference between solubility of manually peeled cassava starch and those made from cassava peeled with NaOH/citric acid except for that made from peeling of TMS 97/2205 which were all significantly diffferent from one snother ($p<0.05$).

Table 4. Effect of Different Peeling Treatments on Some Functional Properties of the Cassava Cultivars' Flour

Cassava variety	Peeling Treatment	Bulk Density (g/cm3)	WBC (%)	Swelling capacity (%)	Solubility (%)
TMS01/1371	Manual peeling	0.43^{b}	98.79^{m}	8.31^{a}	7.07
	NaOH/citric acid	0.43^{b}	87.64^{b}	9.36^{c}	7.17
	NaOH/NaCl	0.46^{ef}	76	8.44^{b}	8.4
TMS30572	Manual peeling	0.46^{ef}	97.46^{c}	8.49^{a}	7.30^{a}
	NaOH/citric acid	0.43^{b}	89.47^{a}	9.57^{b}	8.76^{c}
	NaOH/NaCl	0.46^{ef}	94.74^{b}	9.25^{b}	8.20^{b}
TMS92/0326	Manual peeling	0.47^{f}	98.31^{c}	8.76^{b}	7.65^{b}
	NaOH/citric acid	0.46^{de}	91.12^{a}	8.27^{a}	7.26^{a}
	NaOH/NaCl	0.45^{d}	96.47^{b}	9.77^{c}	8.24
TMS9102324	Manual peeling	0.41^{a}	93.67^{c}	8.20^{a}	7.12^{a}
	NaOH/citric acid	0.42^{a}	92.51^{b}	8.77^{b}	7.45^{b}
	NaOH/NaCl	0.43^{a}	90.39^{a}	9.46^{c}	8.76^{c}
TMS97/4763	Manual peeling	0.41^{a}	97.46^{b}	8.57^{a}	7.23^{a}
	NaOH/citric acid	0.42^{a}	90.10^{a}	8.46^{a}	7.73^{a}
	NaOH/NaCl	0.45^{d}	98.77^{c}	9.65^{a}	8.37^{a}
TMS97/2205	Manual peeling	0.45^{d}	97.91^{c}	8.36^{a}	7.42
	NaOH/citric acid	0.43^{b}	90.76^{a}	8.56^{b}	7.65^{b}
	NaOH/NaCl	0.44^{c}	91.73^{b}	9.04^{c}	8.01^{c}

Means in the same column with the same superscripts are not significantly different from one another ($p<0.05$)

WBC: Water Binding Capacity

Table 5. Effect of the Different Peeling Treatments on the Functional Properties of the Cassava Cultivars' Starch

Cassava variety	Peeling Treatment	Bulk Density (g/cm3)	WBC (%)	Swelling capacity (%)	Solubility (%)
TMS01/1371	Manual peeling	0.43^{a}	105.80^{b}	9.46^{b}	8.75^{ef}
	NaOH/citric acid	0.44^{a}	110.31^{d}	9.67^{ef}	8.46^{bcde}
	NaOH/NaCl	0.41^{a}	113.20^{f}	10.46^{l}	9.80^{f}
TMS92/0326	Manual peeling	0.42^{a}	105.63^{b}	9.72^{efg}	8.63^{cdef}
	NaOH/citric acid	0.42^{a}	120.76^{l}	9.65^{cdef}	8.59^{cdef}
	NaOH/NaCl	0.41^{a}	112.90^{e}	10.36l	9.54^{f}
TMS30572	Manual peeling	0.41^{a}	114.41^{g}	9.57^{bcde}	8.76^{ef}
	NaOH/citric acid	0.42^{a}	118.50^{i}	9.95^{hi}	8.64^{cdef}
	NaOH/NaCl	0.41^{a}	110.18^{d}	$10.^{16j}$	9.52^{f}
TMS91/02324	Manual peeling	0.42^{a}	101.12^{a}	9.31^{a}	8.10^{a}
	NaOH/citric acid	0.41^{a}	120.46^{kl}	9.48^{bc}	8.12^{a0}
	NaOH/NaCl	0.52^{a}	110.04^{d}	10.77^{l}	9.65^{g}
TMS97/4763	Manual peeling	0.43^{a}	110.19^{d}	9.66^{def}	8.31^{ascd}
	NaOH/citric acid	0.45^{ab}	120.20^{jk}	9.87^{gh}	8.33^{abc}
	NaOH/NaCl	0.43^{a}	108.40^{c}	10.07^{ij}	8.95^{f}
TMS97/2205	Manual peeling	0.43^{b}	120.05^{j}	9.55^{scd}	8.06^{a}
	NaOH/citric acid	0.43^{b}	120.22^{jk}	9.76^{fg}	8.43^{bede}
	NaOH/NaCl	0.40^{a}	115.23^{h}	10.33^{k}	9.47^{g}

Means in the same column with the same superscripts are not significantly different from one another ($p<0.05$)

WBC: Water Binding Capacity

4. Conclusion

The different peeling treatments had varied effects on the chemical and functional characteristics of the cassava products. In some cassava cultivars chemical peeling resulted in increase of the parameters studied and in some there were significant effects on the quality parameters. It was found out that the cassava products peeled using the process had characteristics which meet stipulated quality standards (Table 5).

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