

Screening of some cassava starches for their potential applications in custard and salad cream productions

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Abstract Custard powder and salad cream are two food products commercially manufactured using different quantities of corn starch. This study aimed at determining the physicochemical properties of some starches extracted from some white and yellow root cassava varieties. The prospective applicability of the cassava starches in custard powder and salad cream production was also determined. The physical, chemical and functional properties of eight cassava starches were determined using standard analytical procedures. Sensory acceptability of the products was also determined using untrained consumer group. Products made from corn starch were used as the reference samples. The physical, chemical and functional properties of the cassava starches varied significantly ($p < 0.05$). The results of multivariate data analysis (principal component and cluster analyses) showed that it was difficult to completely discriminate starches from the yellow fleshed and white fleshed cassava roots. Texture was the most important sensory attribute determining the two products' acceptability. Starch powder dispersibility was found to have significant influence ($p < 0.05$) on the sensory acceptability of the two products. However, starch from a yellow fleshed root (TMS 01/1368) was the most preferred for salad cream making

while starch from a white fleshed root (TMS 30572) was the most preferred for making custard powder. The starches showed high potential to replace corn starch for the respective product manufacture.

Keywords Salad cream · Custard powder · Cassava starch · Sensory acceptability

Introduction

Custard powder is a fine textured food product mainly produced from corn starch to which flavouring and colouring agents are added with or without the addition of egg yolk solids, salt, vitamins, and minerals. Custard is mainly consumed as a breakfast food or complementary foods. On the other hand, salad cream is an emulsified creamy yellow viscous sauce made from mixture of water, vegetable oil, vinegar, and corn starch as major ingredients [1]. However, corn starch which is the main ingredient in custard powder and salad cream production is mainly imported to Nigeria. The importation cost of corn starch in 2010 was about 15 million USD. Literature is very deplete in terms of studies on alternative starch sources for custard and salad cream production. Finding any starch rich plant biomass as suitable substitute to corn will therefore be of great technical and economic benefits to such economies with comparative advantage of producing any.

Cassava as an abundant starchy crop is undergoing repositioning in Nigeria as an economic root crop to have similar status as corn in most starch exporting countries. Nigeria is currently the leading producer of cassava roots worldwide contributing about 54.8 million metric tons of cassava in 2014 [2]. Despite its abundant production, cassava has not found commensurate industrial utilization in

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the country. Conversion of raw cassava roots to dry products such as starch makes it available for many applications. At present, cassava is still mainly processed into traditional food products such as *gari*, *fufu* and *lafun* with few applications in non-traditional food such as tapioca flakes. Therefore, in order to successfully extend its use to a diverse range of new food product, pilot studies to establish its potential application in foods are necessary.

Application of starches in many foods is governed by their functional and chemical properties [3] and starches from different varieties vary in their functionality due to differences in their granular structure and amylose content [4, 5]. Technological properties of cassava starches have been studied previously. Variations in the starch properties have been attributed to factors such genetic background, planting seasons, harvesting date, and so on [6–8]. Some of the major qualities of cassava starch are its ability to gelatinize and form clear paste with little or absence of flavour and reduced lump formation effect. Functional and pasting properties are key parameters that predict the behaviour of a food material and consumers likewise are major determinant of the success of any new food product. Previous studies have shown the potential of elite yellow fleshed cassava to provide additional supply of pro-vitamin A in processed foods [9–11]. It was therefore hypothesised that starches from yellow fleshed cassava roots could have better potential than some well acceptable white fleshed roots in additional food applications. Moreover, studies determining the potential food application of cassava starch as substitute to starches from other sources are scarce in literature.

Therefore this study was conducted to determine the suitability of starches from eight cassava varieties for making two non-indigenous products, namely, custard powder and salad cream. This study was also expected to give idea of starch functionality needed to screen cassava varieties meant for making custard powder and salad cream.

Materials and methods

Materials

Eight cassava varieties (TMS 01/1368, TMS 01/1412, TMS 01/1206, TMS 01/1371, TMS 30,572, TME 419, TMS 95/1632, TMS 98/0581) were harvested at about 15 months after planting from the research farm of the International Institute of Tropical Agriculture (IITA), Mokwa, Niger state located in the Guinea savannah region of Nigeria. The cassava roots were processed immediately after harvesting into cassava starch powders.

Custard powder ingredients such as vanilla flavor, tartrazine, corn starch powder and sugar were purchased an open market (Kuto, Abeokuta, Nigeria). Salad cream ingredients

including mustard powder, sugar, salt, and vinegar were purchased from a supermarket (Shoprite, Ibadan, Nigeria) while vegetable oil and egg were purchased from an open market (Kuto, Abeokuta, Nigeria).

Methods

Cassava starch extraction

The method described by Oyewole and Obieze [11] was used for cassava starch extraction. Fifty kilogram of roots from the eight cassava varieties each were peeled, washed in water and grated with a locally fabricated mechanical grater. The resultant pulp was sieved immediately through a muslin cloth suspended in about 70 L of water. This process separated the fibrous and coarse root materials from the starch pulp. The starch pulp was allowed to settle for 7–8 h before decanting the supernatant. The thick starch cake at the bottom of the pulp was slightly washed and then pressed to remove the remaining water. The starch was dried in a locally fabricated convective oven at 60 °C for 18 h, packed in a polyethylene bag, stored in a covered container and kept in a cold storage for further use. The dried starch was milled and sieved through 106 µm mesh size before further use in the study.

Starch analyses

The proximate composition of the starch samples were determined using AOAC (2000) method of analysis. The swelling power and solubility index at different temperature (60–100 °C) were determined according to the method described by Hirsch et al. (2002). One gram of sample was poured into pre-weighed graduated centrifuge tube appropriately labeled. Then, 15 ml of distilled water was added to the weighed sample in the centrifuge tube and the solution was stirred and placed in a water bath heated at different temperature range (60, 70, 80, 90, 100 °C) for 1 h while shaking the sample gently to ensure that the starch granules remained in suspension until gelatinization occurred. The samples were cooled to room temperature under running water and centrifuged for 30 min at 1000 rpm using a centrifuge (Model 90-1, Jiangsu Zhangji Instruments Company, China). After centrifuging, the supernatant was decanted from the sediment into a pre-weighed petri-dish; the supernatant in the petri-dish was weighed and dried at 105 °C for 1 h. The sediment in the tube was weighed and the reading recorded. The starch swelling power and solubility (%) were respectively determined according to the equations below:

$$\text{Swelling power} = \frac{\text{Weight of swollen sediment}}{\text{Weight of dry starch}}$$

$$\text{Solubility (\%)} = \frac{\text{Weight of dry supernatant}}{\text{Weight of starch sample}} \times 100$$

Dispersibility was determined according to the method of Kulkarni et al. (1991). Ten grams sample was dispersed in distilled water in a 100 ml measuring cylinder and distilled water was added up to 50 ml mark. The mixture was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was noted and percentage dispersibility was calculated as follows:

$$\text{Dispersibility (\%)} = \frac{50 - \text{volume of settled particle}}{50} \times 100$$

Water absorption capacity (WAC) was determined according to the method described by Lin et al. (2006). One gram sample was weighed into clean pre-weighed dried centrifuge tube and mixed with 10 ml distilled water with occasional stirring for one hour. The dispersion was centrifuged at 1500 rpm for 30 min. After centrifuging, the supernatant was decanted and the tube with the sediment was weighed after removal of the adhering drops of water. The weight of water (g) retained in the sample was reported as WAC.

Bulk density was determined according to the method described by Waring et al. (1976). Ten grams of sample was measured into a 50 ml graduated measuring cylinder and gently tapped on the bench top several times until a constant height was attained. The volume of sample was recorded and expressed as grams per millilitre.

Least gelation concentration was determined according to the method of Coffman and Garcia (1977). Ten suspensions (2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 % w/v) in 10 ml distilled water were prepared in test tubes. The test tubes containing the suspensions were heated in a boiling water bath (Model 83, Thelco, USA) for 1 h followed by rapid cooling under running cold tap water. The test tubes were cooled for 2 h at 4 °C and the least gelation concentration was determined as the concentration that did not fall down or slip when the test tube was inverted.

The pasting properties were determined using rapid visco analyzer (RVA) as described by Maziya-Dixon et al. (2005). Three gram of sample was weighed into a test canister and 25 ml of distilled water was added. The solution was inserted into the tower and then lowered into the Visco Analyser system. The slurry was heated automatically from 50 to 95 °C in the RVA Analyser and was cooled back to 50 °C. The contents were rotated at a speed of 160 rpm with continuous stirring with a plastic paddle. The parameters estimated were peak viscosity, trough, setback viscosity, final viscosity, pasting temperature and time to attain peak viscosity.

Custard paste preparation

The modified method described by Abdalla et al. [18] was used for the custard preparation. Fifty gram of each starch sample containing (3.16 % Vanilla + 0.016 % Tartrazine) was suspended in 70 ml of water in a plastic container to make thin slurry. Thereafter, 240 ml of boiling water was added to each of the suspension with continuous stirring for 10 min to produce hot gruel. After preparation, 10 g of sugar was added to each of the samples to modify its taste.

Salad cream preparation

The ingredients used in the salad cream preparation were water, sunflower oil, vinegar, dry cassava starch, salt, sugar, egg yolk and mustard powder. The proportion by weight of these ingredients in the formulation was 44.23, 24.91, 14.89, 7.57, 4.42, 1.77, 1.23 and 0.98 %, respectively. The procedure of salad cream preparation was similar to that described by Babajide and Olatunde [19] with some modifications. Dry cassava starch was first reconstituted with water after which vinegar, salt, sugar and mustard powder were added. The mixture was then cooked until it was translucent. This was then cooled at refrigeration temperature and blended in a warring blender for 1 min after which, egg yolk and vegetable oil were added and then blended for 5 min. The resultant salad cream was then poured into a covered plastic jar and kept in the refrigerator prior to sensory analysis.

Sensory evaluation of the products

The samples of the two products were served to 30 untrained panelists (both male and female) comprising of staff and students from the Federal University of Agriculture, Abeokuta, Nigeria who are usual consumers of each product and were willing to participate in the sensory assessment. The custard gruel samples were served warm in coded transparent cups and scored in terms of appearance, flavour, texture (mouth feel), taste and general acceptability. Freshly prepared salad cream samples were however presented in coded white plastic plates. The attributes evaluated include colour, texture, taste, odour, appearance and overall acceptability. A 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) was used by the panelists to score the two product samples. Between each tasting, natural water was used to rinse the mouth to avoid taste carry over. The evaluation was conducted under uniform fluorescent illumination in the sensory laboratory cubicles.

Data analyses

All experimental data obtained were subjected to analysis of variance (ANOVA) at 95 % significant level and means were separated using Duncan's Multiple Range Tests. Principal component analysis and hierarchical clustering of the cassava root based starch data was performed using XLSTAT and SPSS Statistical packages.

Results and discussion

Proximate composition of the extracted cassava starches

The moisture, protein, fat and ash content of the extracted starches from the cassava roots are shown in Fig. 1. Only the moisture (1.02–1.1.82 %) and ash (0.07–0.48 %) contents of the starch samples differed significantly ($p < 0.05$). It is allowable to detect other proximate components like protein, fat, ash and non-starch carbohydrates in food grade starches. The total sugar did not differ significantly (Fig. 2). The yield of extracted starch from the eight cassava roots in this study ranged from 72.2 to 85.5 % which is within the range of values reported by Nuwamanya et al. [20]. The

ratio of amylase/amylopectin of the cassava varied significantly from 0.19 to 0.40 ($p < 0.05$). This ratio importantly determines the functionality and prospective applications of the starches. The presence of the other components apart from starch primarily measures the starch purity, which is determined by the efficiency of the extraction methods. However, non-starch components could also affect the starch functionality in food applications. Typically, mineral element (or ash) composition has been reported to relate to pasting properties of starches [21]. Hydrophilic groups in protein residues contained in starch may also affect pasting viscosity as compared to cassava starch paste [22]. Also, the pasting temperature increased while the peak and breakdown viscosities of cassava starch decreased with sugar content [23].

Color properties of the cassava starches

Table 1 shows the CIE Lab colour properties of the eight cassava starch varieties. The lightness, greenness (+a) and yellowness (+b) values differed significantly ($p < 0.01$). Ordinarily, it would be expected that yellow fleshed roots will give more yellowish powders. In spite of the root colour difference, the dried starch samples did not show clear demarcation in terms of colour. The reason for the lack of

Fig. 1 Proximate composition of the cassava starches

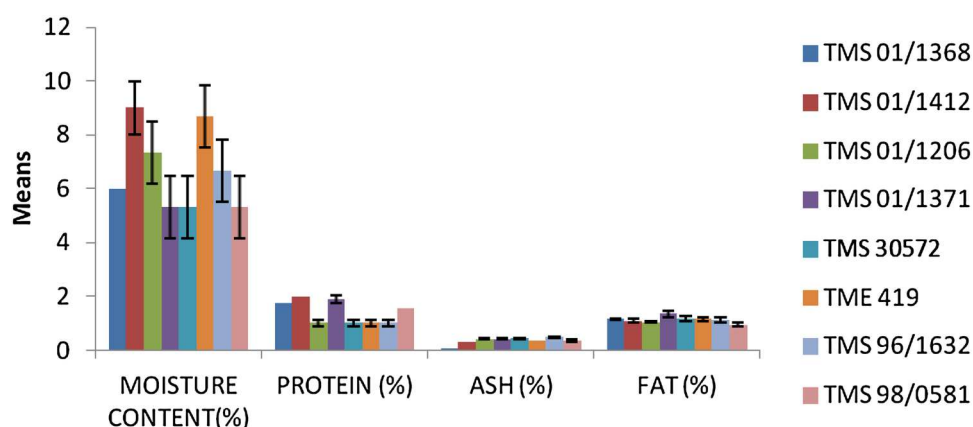


Fig. 2 Some chemical properties of the cassava starches

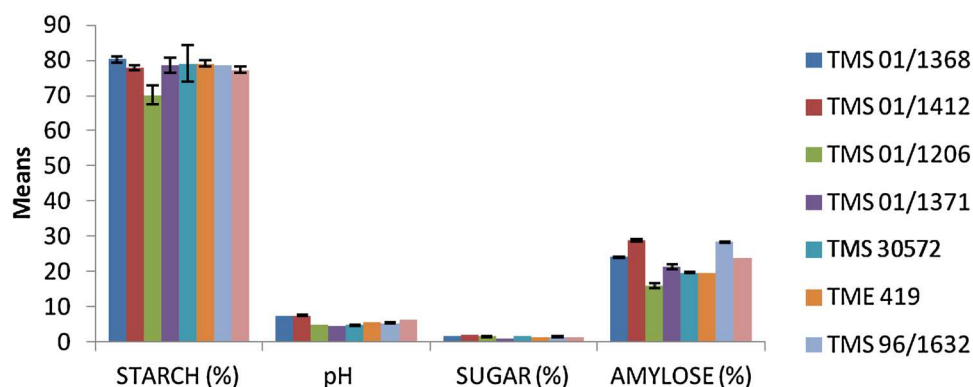


Table 1 CIE lab colour and functional properties of eight cassava starch varieties

Cassava variety	Root flesh colour	L*	a*	b*	Dispersibility (%)	Water absorption capacity (g/g)	Least gelation concentration (%)	Bulk density (g/ml)	Oil absorption capacity (g/g)	Dispersibility (%)
TMS 01/1368	Yellow	101.05 ^e	0.33 ^b	7.87 ^d	66.07	0.57	2.67	0.83 ^c	0.99 ^a	66.07
TMS 01/1412	Yellow	96.49 ^a	1.18 ^g	7.78 ^c	66.80	1.00	2.67	0.91 ^d	1.22 ^c	66.80
TMS 01/1206	Yellow	99.80 ^b	0.61 ^e	8.20 ^e	65.67	0.93	2.00	0.67 ^a	1.13 ^b	65.67
TMS 01/1371	Yellow	117.17 ^f	0.14 ^a	13.24 ^g	64.80	1.20	2.67	0.75 ^b	0.97 ^a	64.80
TMS 30572	White	101.84 ^d	0.37 ^c	7.38 ^b	65.57	0.93	2.00	0.76 ^b	1.52 ^e	65.57
TME 419	White	105.90 ^e	0.96 ^f	6.96 ^a	65.77	0.97	3.33	0.77 ^b	1.48 ^e	65.77
TMS 96/1632	White	102.29 ^d	1.27 ^b	8.96 ^f	66.20	0.88	3.33	0.81 ^c	1.23 ^c	66.20
TMS 98/0581	White	99.47 ^b	0.41 ^d	7.00 ^a	65.00	0.94	4.67	0.83 ^c	1.36 ^d	65.00

Means followed by the same alphabet in the same column are not different significantly from each other ($p < 0.05$)

clear demarcation is that most of the pigment in the yellow fleshed roots could have been lost during starch extraction due to their water solubility and at the drying stage due to thermal degradation.

Functional properties of cassava starches

Table 2 shows the mean values of functional properties of the cassava starch powders. Functional properties of food materials determine their potential food applications. Powder dispersibility is a property that indicates its rate of reconstitution in water. Higher powder dispersibility value indicates lower tendency to form lumps when used in making puddings. The mean value of dispersibility of the starch powder which ranged from 64.80 to 66.80 % did not differ significantly ($p > 0.05$). The dispersibility values obtained from this study are lower than the reported values of 82–89.50 % [24], 85.40 % [25] and 84 % [26] for different cassava starch powders. The lower value observed in this study in comparison to values reported in the literature may be due to genetic differences, particle size and moisture content of the cassava starch powders. Increased moisture content and particle size of food powder is associated with higher dispersibility [27]. Food powders having higher lump formation tendency during reconstitution may require more mixing energy to reduce lumping.

Water absorption capacity (WAC) measures the amount of water held by the starch granules at room temperature. WAC of the starches which ranged from 0.57 to 1.2 g/g (Table 1), did not differ significantly ($p > 0.05$) with TMS 01/1368 having the lowest while TMS 01/1371 had the highest. Since the values of WAC of starches depend on the structure and compactness of the starch granules, the insignificant difference in the.

WAC of the eight cassava starches might be due to their similarity in terms of granular structure [28, 29]. In spite of their insignificant difference in the WAC, the oil absorption capacity (OAC) which ranged from 0.97 to 1.48 g/g starch differed significantly ($p < 0.05$).

Least gelation concentration (LGC) is the least quantity of starch or starch blends required to form a gel. The least gelation concentration (LGC) which ranged from 2.00 to 4.67 % was significantly different among the starch samples. However, the LGC values observed in this study is in agreement with the findings of Onitilo et al. [24] who reported the range of 2–4.67 % and Adebawale et al. [25] who reported 2 % for different cassava starch.

Bulk density (BD) is a measure of the degree of coarseness of a powder or flour sample. The bulk density (BD) of the cassava starch which ranged from 0.67 to 0.91 g/ml was found to be significantly different. TMS 01/1206 had the lowest while TMS 01/1412 had the highest. The BD values of the cassava starch powders are in agreement with

Table 2 Linear regression parameter showing response of swelling power and solubility to temperature

Variety	Solubility (%)			Swelling power		
	A	B	r ²	A	B	r ²
TMS 01/1368	0.347	−20.667	0.8918	0.032	1.809	0.9614
TMS 01/1412	0.477	−29.133	0.9655	0.031	1.638	0.9848
TMS 01/1206	0.370	−21.467	0.9528	0.036	0.725	0.9872
TMS 01/1371	0.470	−27.533	0.9742	0.056	0.751	0.9287
TMS 30572	0.407	−23.333	0.8971	0.058	−0.742	0.9623
TME 419	0.480	−26.533	0.9766	0.024	1.977	0.9662
TMS 96/1632	0.370	−19.667	0.9898	0.099	−2.393	0.9767
TMS 98/0581	0.423	−25.267	0.9842	0.099	−2.307	0.9632

those reported by Adebawale et al. [25] and Koh and Long [30] for cassava starch samples of different cassava genotype. Bulk density of food particle primarily determines the packaging volume required for the product.

The swelling power (SP) of the cassava starch varieties at different temperature is presented in Fig. 3. Swelling power is a measure of the ability of starch to imbibe water and swell at different temperature. The starch granule swelling increased linearly with temperature ($R^2=0.93–0.99$, $p<0.05$) as shown in Table 2. The increased swelling power of the starches with increase in temperature is in agreement with the findings of Agunbiade et al. [31], Adebawale et al. [25, 33], and Koh and Long [30]. A previous study had also shown that cassava had greater swelling capacity at temperature of 60–80 °C in comparison with potato, sweet potato, maize, wheat, millet and sorghum [33]. The increased swelling of starches has been explained to be due to weakening of force of attraction between the starch molecules with increase in temperature thereby enhancing more water uptake and concomitant granule swelling. Result further indicates that response of swelling to temperature was highest in TMS 96/1632 and TMS 98/0581 while it was lowest in TME 419.

Figure 3 shows the changes in solubility index of the cassava starches with temperature. The solubility index

also increased linearly with temperature ($r^2=0.89–0.99$, $p<0.05$) as shown in Table 2. This is similar with the findings of Adebawale et al. [28] and Gbadamosi and Oladeji [34] for cassava starch. The response of starch solubility to temperature was highest in TME 419 and least in TMS 96/1632.

Pasting properties of cassava starch and custard powder

The pasting properties of cassava starch powders are presented in Table 3. The mean values of peak viscosity of the starch samples ranged from 193 to 463 RVU. Peak viscosity of TMS 01/1368 was almost thrice of TMS 01/1371. Peak viscosity is the maximum viscosity attained during or immediately after heating portion as depicted in the pasting test. It is an index of the ability of starch-based food to swell freely before their physical breakdown. The pasting properties of the cassava starch-based custard powders were significantly different ($p<0.05$).

Trough is the minimum viscosity value in the constant temperature phase of the RVA pasting profile and it measures the ability of the paste to withstand breakdown during heating. The trough viscosity, which ranged from 81.5 to 222.5 RVU, differed significantly among

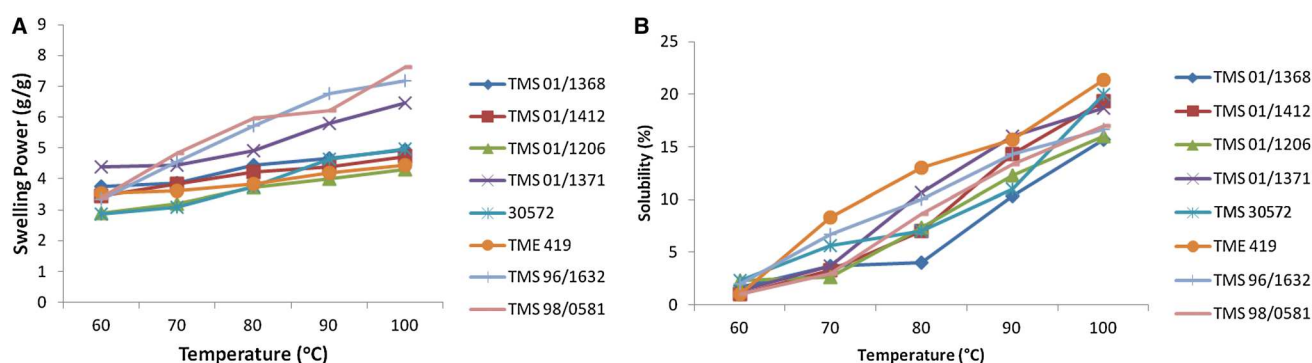
**Fig. 3** Effect of temperature on the swelling power (a) and solubility (b) of the cassava starches

Table 3 Pasting properties of the cassava starches

Cassava variety	Pasting viscosities (RVU)					Peak time (min)	Pasting Temp (°C)
	Peak	Trough	BKD	Final	SBK		
TMS 01/1368	193.50 ^d	81.46 ^d	112.04 ^e	123.42 ^c	41.96 ^b	4.30 ^{ab}	73.80 ^a
TMS 01/1412	276.08 ^c	114.33 ^c	161.75 ^{cd}	173.58 ^b	59.25 ^a	4.07 ^{ab}	73.85 ^a
TMS 01/1206	255.71 ^{cd}	119.79 ^{bc}	135.92 ^{de}	153.71 ^{bc}	33.92 ^b	4.13 ^{ab}	75.48 ^a
TMS 01/1371	462.79 ^a	222.54 ^a	240.25 ^a	280.92 ^a	58.38 ^a	3.93 ^b	73.48 ^a
TME 419	263.79 ^c	120.50 ^{bc}	143.29 ^{de}	164.71 ^b	44.21 ^b	4.17 ^{ab}	74.30 ^a
TMS 30572	343.29 ^b	150.00 ^b	193.29 ^{bc}	181.00 ^b	31.00 ^b	4.14 ^{ab}	75.10 ^a
TMS 96/1632	370.38 ^b	147.63 ^b	222.75 ^{ab}	179.46 ^b	31.83 ^b	4.04 ^{ab}	62.70 ^a
TMS 98/0581	250.50 ^{cd}	125.46 ^{bc}	125.04 ^{de}	164.33 ^b	38.88 ^b	4.44 ^a	75.90 ^a

Means followed by the same alphabet in the same column are not different significantly from each other ($p < 0.05$)

the starches ($p < 0.05$). It was the most varied among the pasting viscosities measured ($CV = 30.46\%$). The difference between the peak and trough viscosities, also known as breakdown viscosity, is an index of cooking stability. The breakdown viscosity (BKD) ranged from 22.75 to 240.25 RVU. Higher value of BKV for a starch indicates lesser cooking stability. Thus, TMS 01/1368 and TMS 01/1371 showed the highest and least cooking stabilities, respectively.

Setback viscosity (SBV) is the stage of retrogradation or re-ordering of starch molecules during cooling. Setback viscosity ranged from 31.00 to 58.38 RVU ($CV = 26.26\%$). The differences were statistically significant ($p < 0.05$). TMS 30572 had the lowest and 01/1412 had the highest setback value. This probably suggests that starch of TMS 30572 has greatest resistance to retrogradation. For many starchy foods, SBV often influences their textural characteristics. Final viscosity also known as the cold paste viscosity is that viscosity attained by the starch paste after

cooling [35]. The final viscosity ranged from 123.42 to 280.92 RVU.

The temperature attained at the onset of the rapid increase in viscosity is also known as the pasting temperature while the peak time measure the time required for the paste to reach peak viscosity. Both parameters provide an indication of the ease of cooking and the energy requirement for cooking a starchy suspension. Peak times and temperatures for the cassava starches ranged from 3.93 to 4.44 min and 62.70 to 75.90°C, respectively (Table 4). There were slight differences among the starches in terms of peak time ($CV = 3.78\%$) and pasting temperature ($CV = 5.86\%$). TMS 96/1632 and TMS 98/0581 had the lowest and highest values, respectively.

The pasting behaviour of the formulated custard powder was also studied to understand how other ingredient added could affect the pasting property of the product. Generally, it was observed that about 3.9–59.1 % reduction in the pasting viscosity values of the cassava starch were observed

Table 4 Sensory acceptability custard gruel and salad cream made from cassava and corn starch powders

Sample	Custard powder gruel					Salad cream					
	Appearance	Flavour	Texture	Taste	Overall acceptability	Color	Texture	Taste	Odour	Sheen	Overall acceptability
TMS 01/1368	6.00 ^{bc}	5.90 ^{abc}	6.26 ^{bc}	5.97 ^{abc}	5.97 ^{bc}	7.60 ^{ab}	7.63 ^a	6.70 ^a	6.90 ^a	6.10 ^a	7.23 ^{ab}
TMS 01/1412	4.33 ^a	5.47 ^a	5.33 ^a	5.23 ^a	4.90 ^a	7.00 ^c	6.90 ^b	6.67 ^a	6.57 ^{ab}	6.07 ^a	6.73 ^{bc}
TMS 01/1371	6.97 ^{cd}	5.50 ^a	5.67 ^{abc}	5.07 ^a	5.67 ^b	6.20 ^d	6.03 ^{cd}	5.90 ^b	5.46 ^{cd}	6.03 ^a	6.13 ^d
TMS 01/1206	6.10 ^{bcd}	6.47 ^{bcd}	5.97 ^{abc}	5.73 ^{ab}	6.23 ^{bc}	6.00 ^d	3.80 ^f	4.50 ^c	4.80 ^d	5.73 ^a	4.83 ^e
TMS 96/1632	5.77 ^{bc}	5.63 ^{ab}	5.83 ^{abc}	5.63 ^{ab}	5.80 ^{bc}	7.07 ^{bc}	6.17 ^c	5.27 ^b	5.33 ^{cd}	6.30 ^a	5.97 ^c
TME 98/581	5.60 ^b	5.17 ^a	5.57 ^{ab}	5.70 ^{ab}	5.80 ^{bc}	5.97 ^d	5.47 ^{de}	5.67 ^b	5.47 ^{cd}	5.80 ^a	5.91 ^d
TME 419	6.13 ^{bcd}	6.70 ^{cd}	6.43 ^{bc}	6.37 ^{bc}	6.30 ^{bc}	6.77 ^c	5.17 ^e	5.77 ^b	5.87 ^{bc}	5.97 ^a	6.20 ^d
TMS 30572	6.63 ^{cd}	6.63 ^{cd}	6.33 ^{bc}	6.40 ^{bc}	6.43 ^{bcd}	7.13 ^{bc}	5.80 ^{cde}	5.70 ^b	5.83 ^{bc}	6.27 ^a	6.43 ^{cd}
Corn starch	7.23 ^d	6.00 ^{abc}	6.53 ^c	6.83 ^c	7.13 ^d	7.87 ^a	7.07 ^{ab}	6.57 ^a	6.40 ^{ab}	6.13 ^a	7.30 ^a

Means followed by the same alphabet in the same column are not different significantly from each other ($p < 0.05$)

when compared with that of custard powder (Fig. 4). In spite of the addition of small quantities of ingredients (flavourant and colourant powders), all the pasting viscosities except setback viscosity reduced implying that the interaction of the ingredients with the starch could have resulted into restricted starch granule swelling. In certain starches (TMS 01/1206, TMS 30572 and TMS 96/1632), setback viscosity was increased in the formulated custard powder. This implies increased retrogradation tendency in their custard paste. The reduction in breakdown and final viscosities respectively signifies greater cooking stability and reduced cold paste viscosity of the custard powders.

Sensory acceptability of the products

Table 5 shows the sensory acceptability scores of custard pastes and salad creams from the eight cassava starch varieties in comparison with that from corn starch custard as the reference. Oneway analysis of variance (ANOVA) indicated that the sensory acceptability of the products differed significantly ($p < 0.05$). This is in contrast with the finding of Eke-Ejiofor [36] who reported insignificant difference between acceptability of salad cream produced from different starches in spite of their different biological origins (cassava, sweet potato and trifoliate yam). The reference samples of custard paste and salad cream had the highest acceptability scores. Starches from TMS 30572 and TMS 01/1368 gave the most preferred custard paste and salad cream, respectively. Their scores were similar to that of the respective reference samples made from corn starch. Using general linear model approach, the texture of custard paste and salad cream had the most significant influence on its overall acceptability. This result also underscores the fact that starch properties having the most significant

Table 5 Effect of individual sensory attributes on the overall acceptability of the products

Custard paste			Salad cream		
Attribute	Coefficient	Sig	Attribute	Coefficient	Sig
Constant	0.284	0.353	Constant	0.236	0.313
Appearance	0.154	0.000	Colour	0.167	0.000
Flavour	0.145	0.002	Texture	0.273	0.000
Texture	0.454	0.000	Taste	0.263	0.000
Taste	0.198	0.000	Odour	0.093	0.009
–	–	–	Sheen	0.190	0.000
R ²	0.632		R ²	0.796	
Sig. P	0.000		Sig. P	0.000	

correlation with the products' texture could indicate the best cassava starch for making custard powder.

Discriminating the cassava varieties based on measured starch properties

In order to establish basis for discriminating the cassava varieties in terms of the twenty-four distinct starch properties measured, principal component analysis (PCA) was conducted using Pearson's (n) correlation approach. Moisture content was however excluded as other chemical components were converted to dry matter basis before analysis. The first four principal components (F1-F5) explained about 96 % of the total variability of the data. This implies that the variables identified as having significant loading effects on each factor can be used as discriminant variables. The list of variables with significant loading effect on each component is shown below:

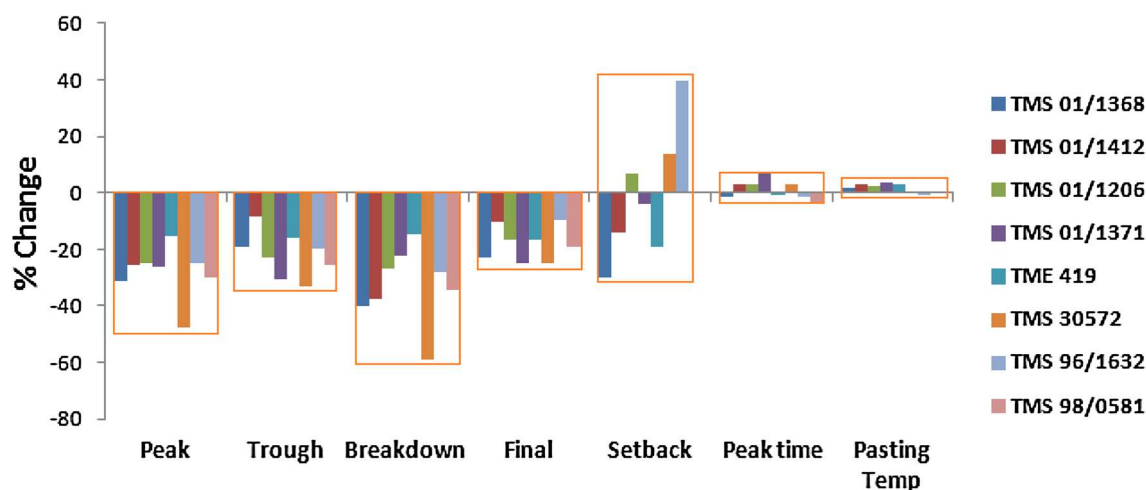


Fig. 4 Percent changes in the pasting properties of cassava starches when formulated to respective custard powders

F1	CHO > a* > L* > PkTm > FV > Trgh > PV > BV > Amy > WAC > b* > LGC
F2	Ash > pH > SolG > Pro > Fat
F3	SwG > SBV > PTP
F4	BD > Disp
F5	OAC

Where CHO is carbohydrate, PkTm is peak time, FV is final viscosity, Trgh is trough, PV is peak viscosity, BV is breakdown viscosity, Amy is amylose content, WAC is water absorption capacity, LGC is least gelation concentration, SolG, solubility gradient, Pro is protein content, SwG swelling gradient, SBV setback viscosity, PTP pasting temperature, BD is bulk density, Disp is dispersibility, and OAC is oil absorption capacity. Based on the measured

properties, it was not possible to distinguish the starches based on the criteria of yellow and white root varieties. However, TMS 01/1371 was the most distinct (Fig. 5) probably due to its especially high pasting viscosities.

Correlating the starch properties with product quality

Results shown in Table 6 further indicate that dispersibility and bulk density of starch powder had significant positive correlations with the appearance scores of custard paste and as well as consistency, taste and odour of salad cream ($p < 0.05$). Also, the setback viscosity had negative correlations with overall acceptability score of custard paste. It is interesting to note that, out of all the starch properties determined, dispersibility and bulk density (BD) unexpectedly

Fig. 5 Dendrogram showing linkages between the cassava varieties based on the measured starch properties

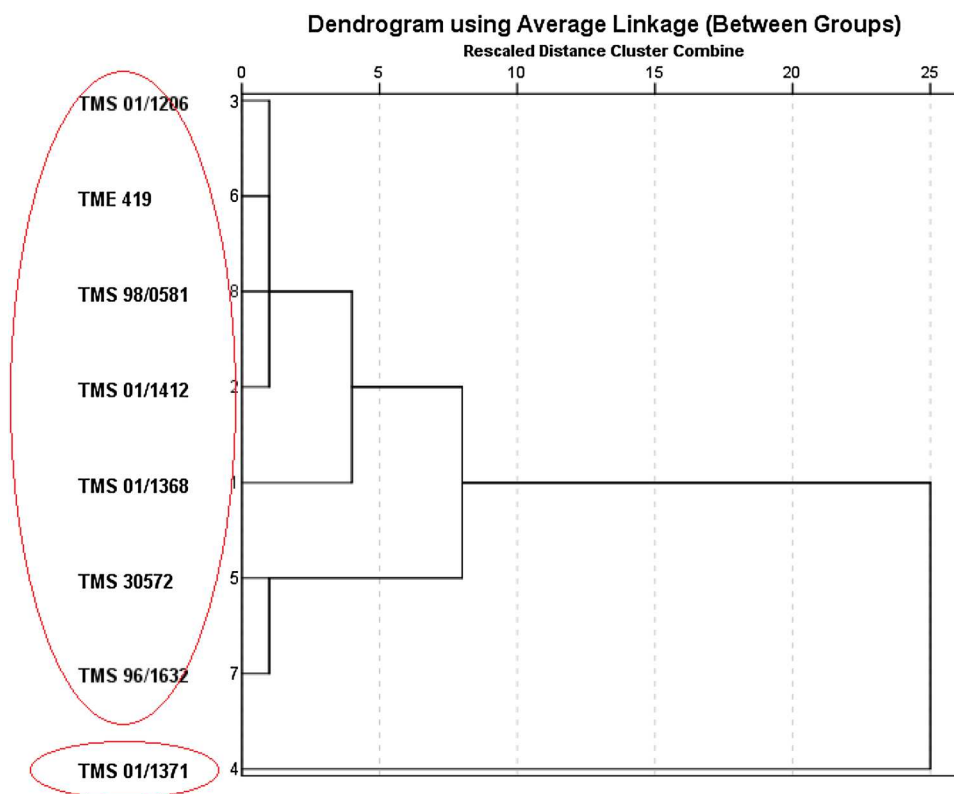


Table 6 Significant correlations between functional properties and sensory acceptability of products

Product	Sensory attribute	Starch property		
		Dispersibility	Bulk density	Setback viscosity
Custard paste	Appearance	−0.734*	−0.748*	—
	Overall acceptability	—	−0.740*	−0.725*
Salad cream	Consistency	0.775*	—	—
	Taste	0.790*	—	—
	Odour	0.724*	—	—
	Overall acceptability	0.718*	—	—

* $p < 0.05$

showed more significant correlation with acceptability of the starch based products. Up to date, studies that reported significant correlation of BD of powdered ingredients on food product quality are scarce. The reason for the significant correlation of BD with sensory acceptability of custard paste is not clear yet.

However, the lack of significant correlation of sensory scores of salad cream with any physical or functional properties of starch powder except dispersibility is understandable. It may be due to the fact that starch contributes little proportion (<8 %) of the product. However, the strong positive influence of dispersibility on the sensory acceptability underscores the need to ensure proper dispersion of the starch during ingredient mixing regardless of starch source to enhance salad cream quality. Also, acceptability of custard paste is expected to depend on the pasting properties of the starch since its aqueous slurry is cooked before consumption. Only setback viscosity of the starches showed significant negative correlations with overall acceptance of custard paste. It should be noted that the setback viscosity was the most widely altered among other pasting viscosities of formulated custard (Fig. 4). Setback value indicates the degree of thickening of starchy paste after cooling. Increased paste setback had weak negative correlation with texture score ($r = -0.523$, $p > 0.05$). Higher paste thickness may reduce ease of swallowing. This could explain the observed reduction of acceptability scores of custard paste with increased setback viscosity values. It should also be mentioned that the reason for the observed significant negative influence of dispersibility on the appearance of custard paste is not yet clear.

Conclusions

This study has shown that dry starch samples obtained from some eight elite cassava roots had significantly different physical, chemical and functional properties. Based on the properties measured, distinct clustering of the starch powders as from either white or yellow fleshed root was impossible. Sensory acceptability scores of salad cream were positively influenced by increased dispersibility of starch powder. On the other hand, starch dispersibility and setback viscosity turned out to affect the sensory acceptability of custard paste negatively. The most acceptable cassava starch for making salad cream and custard powder was from TMS 01/1368 (yellow fleshed root) and TMS 30572 (white fleshed root), respectively. Their starches had comparable acceptability with corn starch which is commonly used for commercial manufacture of the two products.

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