Received: 28 February 2020 | Revised: 15 May 2020 | Accepted: 29 May 2020

DOI: 10.1111/jfpp.14662

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ORIGINAL ARTICLE

Journal of Food Processing and Preservation | Institute of Food Science + Technology ifst | WILEY

Physicochemical properties, rheology, and storage stability of salad creams made from different cassava starch varieties

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Funding information
German Federal Ministry for Education and Research (BMBF); Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Abstract

The use of cassava starch as potential substitute for corn starch in the production of salad cream (SC) may contribute to sustainable utilization of cassava roots. This study investigated the physicochemical properties, rheology, and storage stability of SC made with starches from eight cassava varieties. SC produced was stored in an airtight plastic jar for 3 months at ambient temperature (25 ± 2°C). Changes in the physicochemical properties, rheology, and storage stability of the stored SC samples were determined using standard methods. There was a significant decrease ($p < .05$) in the solid contents of the SC while the peroxide increased with storage period. There was a significant increase ($p < .05$) in the total plate count (TPC) of the SC samples with storage period. This study further showed that the SC samples were all chemically and microbially stable considering the standards for peroxide value (PV) (<10 meg/kg) and TPC (<10^4 cfu/g) within the 3 months storage.

Practical applications

The salad cream (SC) consumed in Nigeria is mainly imported and expensive. Local brands of the product are scarce in the grocery. SC is produced majorly from modified corn flour or starch with other ingredients. To make local manufacture of SC economically feasible, it is practically imperative to find a locally available replacement for corn starch. This study was then conceived to screen starches from some elite cassava varieties for use in SC production. It has been established from this study that the cassava starches tested could be a suitable substitute for corn starch for the production of SC. However, the most stable SC from textural point of view was derived from a yellow fleshed cassava variety (TMS 1206), which is very important for the consumer preference. With appropriate addition of other ingredients in the production, consumers are assured of best quality SC.

1 | INTRODUCTION

Starch is one of the major derivatives of fresh cassava roots. It accounts for 30%–35% of fresh cassava roots (Oghenejoboh, 2012). Cassava starch is a highly suitable material for food and industrial use. It is edible, nontoxic, and functionally important in the food and nonfood sectors of industry (Ayetigbo, Latif, Abass, & Müller, 2018). Cassava starch is used to produce variety of value-added products such as sweeteners, alcohol, acids, and other chemicals (Sriroth, Piyachomkwan, Santisopasri, & Oates, 2001). Cassava starch is used in industries due to its high yield, very low cost, and unique characteristics such as a clear viscous

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paste (Sriroth et al., 2001). These unique characteristics of cassava starch make it advantageous for use in food applications such as tapioca grits (Eke, Achinewhu, & Sanni, 2010), and salad cream (SC) (Ashaye, Sanni, & Arowosafe, 2010; Eke-Ejiofor & Owuno, 2014).

Salad cream belongs to a class of foods commonly referred to as salad dressing. According to Food and Drug Administration (FDA), salad dressing is defined as a semisolid emulsified food with the same ingredient and optional ingredients as mayonnaise with the exception of cooked starch paste (Karas, Skvarãa, & Îlender, 2002). There are two types of salad dressing, namely, pour-able and spoon-able dressing which vary in flavor, chemical, and physical properties (especially viscosity). The example of spoon-able salad dressing is mayonnaise and the pour-able one is SC (Babajide & Olatunde, 2010). SC is an emulsified creamy yellow viscous sauce made from mixture of water, vegetable oil, vinegar, and maize starch as major ingredients (Eke-Ejiofor & Owuno, 2014). It is popularly consumed with salad, which is a popular ready-to-eat dish often containing raw or cooked vegetables usually served chilled or at a moderate temperature. The inclusion of SC in vegetable salad improves the taste of the vegetables thus more vegetables could be consumed for more health benefits, asides the nutritional benefits of the cream. Starch serves as a stabilizer, gelling, binding, thickening, and emulsifying agent in commercial salad dressings (Schlesinger & John, 1996). The possibility of using cassava starch in SC preparation was recently reported by Adebayo, Otunla, and Ajao (2009) using different cassava starch varieties, Ashaye et al. (2010) using cassava starch and Eke-Ejiofor and Owuno (2014) using cassava and sweet potato starches. The authors concluded that cassava starch based SCs compared favorably with commercial salad in chemical composition, functional properties, viscosity and sensory attributes. Our previous study (Akinwale et al., 2016), which corroborated the applicability of cassava starch as potential maize substitute in SC production further indicated that SC from yellow fleshed roots were more preferred to that from white fleshed roots. There is, however, paucity of information on the storage stability of SCs from cassava starches. Information on the storage stability of cassava starch based SC could reinforce the drive toward commercial application of cassava starch as substitute for corn in SC making.

The objectives of this study were to determine changes in the physicochemical properties and rheology of ambient stored SC from different cassava starches, and also to determine the storage stability of cassava starch based SC from different varieties.

2 | MATERIALS AND METHODS

Eight fresh cassava varieties (TMS 01/1368, TMS 01/1412, TMS 01/1206, TMS 01/1371, 30572, TMS 419, TMS 96/1632, TMS 98/0581) were harvested from the International Institute of Tropical Agriculture, Research Farm, Mokwa, Niger State. Mustard, sugar, salt, vinegar, vegetable oil, and egg were purchased from a supermarket (Shoprite, Ibadan, Nigeria) and an open market (Kuto market, Abeokuta, Nigeria).

2.1 | Cassava starch extraction

The method described by Oyewole and Obieze (1995) 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 hr before decanting the supernatant. The sediment (starch) dried in a locally fabricated convective oven at 60°C for 18 hr, 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.

2.2 | SC preparation

The ingredients used in the SC 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 SC preparation was similar to that described by Babajide and Olatunde (2010) 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 SC was then poured into a covered plastic jar.

2.3 | Chemical analysis

The proximate composition of the starch samples were determined using AOAC methods of analysis (AOAC, 2010).

2.4 | Determination of pH

This was determined using a digital pH meter (Model HI 2210, Hanna Instrument Inc., USA). Standardization of the pH meter was carried out using buffer solutions of pH 7 and 4. About 1.5 g of starch sample was dissolved in beaker with 10 ml of distilled water and stirred properly. The pH meter was inserted into the solution and the reading taken.

2.5 | Determination of sugar and starch

The starch and sugar content were determined using the method of (Dubois, Gillies, Hamilton, Rebers, & Smith, 1956; Eke et al., 2010). About 0.2 g of the sample was weighed into a centrifuge tube with 1 ml of 100% ethanol, 2 ml of distilled water, and 10 ml of hot ethanol. The mixture was vortexed and centrifuged for 10 min at 2,000 rpm using Sorvall centrifuge (Newtown, Connecticut, USA), model GLC-1.

The supernatant was decanted into another centrifuge tube; this was used for sugar determination and the sediment was used for starch determination. For sugar determination, 9 ml of distilled water was added to the supernatant and was vortexed. An aliquot of 0.2 ml was then pipetted into a test tube and 0.8 ml of distilled water, 0.5 ml of phenol, and 2.5 ml of concentrated H_2SO_4 were added and vortexed. The sample was allowed to cool and the absorbance was read on a spectrophotometer, model spectronic 601, Milton Roy Company, USA, at 490 nm wavelength.

$$\%\text{Sugar} = \frac{\text{Absorbance} - \text{Intercept} \times \text{Dilution factor} \times \text{Volume}}{\text{Weight of sample} \times \text{Slope} \times 10{,}000}$$

For starch determination, 7.5 ml of perchloric acid was added to the sediment and allowed to stand for 1 hr; then, 17.5 ml of distilled water was added to it and vortexed. An aliquot of 0.05 ml of the solution was pipetted into a test tube; 0.95 ml of distilled water, 0.5 ml of phenol, and 2.5 ml of H_2SO4 were added and vortexed. The mixture was allowed to cool and absorbance was read on a spectrophotometer (Model 601 Milton Roy Company, USA), already standardized at 490 nm wavelength.

$$\%\text{Starch} = \frac{\text{Absorbance} - \text{Intercept} \times \text{Dilution factor} \times \text{Volume} \times 0.9}{\text{Weight of sample} \times \text{Slope} \times 10{,}000}$$

2.6 | Determination of color

This was determined using color meter (CR-410, Japan). The colorimeter operates on the CIE (Commission Internationale de l'Eclairage) L^*, a^*, b^* color scheme. Multiple measurements of several points on samples were made. After calibrating the instrument by counting a zero calibration mask followed by white calibration plate, about 3 g of starch were put in a transparent polythene bag and the color meter was placed on the sample by allowing the sensor to touch the sample. The reading was taken directly for L^*. The instrument displays three-dimensional color difference in uniform color space (Lab) coordinates. Uniform color space defines three directions, a Light to Dark direction, called L^*, a Red to Green direction called a^*, and a blue to yellow direction called b^* (Petterson, McWatters, Hung, Chinnan, & Phillips, 2002).

2.7 | Determination of total solids

About 3 g of sample were weighed into a flat petri-dish heat on steam bath for 15 min, exposing maximum bottom to live steam. It was then heated for 3 hr in an air oven at 100°C, and then, cooled in a desiccator and weighed quickly. The % Residue was reported as total solid.

$$\%\text{Total solids} = \frac{W_2 - W_1}{S} \times 100.$$

2.8 | Determination of titratable acidity (TTA as % lactic acid)

Twenty grams of sample were weighed into a warring blender and mixed for 15 s at low speed and for 1 min at high speed. The mixture was filtered and made up to volume with 200 ml of distilled water and this was titrated against 0.01 M of NaOH.

$$\%\text{TTA}_{(\text{as lactic acid})} = \frac{9 \times N_2 \times V_2 \times V_0}{V_1 \times P}$$

where N_2 = Normality or molarity of NaOH, V_2 = Titer Volume, V_1 = Volume of extract used, V_0 = Total Volume of extract (which is 200 ml), P = Weight of sample taken.

2.9 | Determination of peroxide value

Peroxide value (PV) was determined as described by (AOCS, 1989; Tolve, Condelli, Can, & Tchuenbou-Magaia, 2018). A mixture of glacial acetic acid and chloroform in the ratio 3:2 v/v, respectively, was prepared and 20 cm^3 of it were pipetted out and added to 1 g of each of the samples weighed into a 250 ml of conical flask. 0.5 ml of potassium iodide solution was added to the mixture and the solution obtained was titrated with 0.01 M of Na_2SO_3 until the orange color almost disappeared, and then, 0.5 ml of starch indicator was added, the titration continued until the blue color disappeared. The flask content was shaken vigorously near the end point to ensure that all the iodide was liberated from chloroform layer. The preparation of blank was performed in a similar way.

$$\text{Peroxide value} = \frac{M\left(V_a \times V_b\right)}{W}$$

M = Molarity of $NaSO_3$, W = Weight of the sample, V_a = Volume of the sample, V_b = Volume of the Na_2SO_3 (test titer).

2.10 | Rheological properties

The viscosity of different cassava starch based SC samples were measured in triplicates using a Digital Rotational Brookfield Viscometer, Model DV-E, Brookfield Engineering Laboratories Middleboro, USA). Three readings were taken per sample at 20, 30, 40, and 60 min rotation at each speed (30, 60, and 100 rpm). Spindle No 5 was used for all measurements. A 600 ml beaker was used for

all measurement with the viscometer guard leg on. The samples were poured into the beaker to reach a level that covered the immersion groove on the spindle shaft. All viscosity measurements were carried out immediately after preparing the SC.

2.11 | Storage studies of cassava starch based SC

The SC samples were poured in a covered plastic jar, labeled and stored under ambient temperature (25 ± 2°C) for 3 months. Chemical parameters such as protein, moisture content, ash, starch, sugar, PV, color, fat, total solids (TS), total titratable acidity (TTA), and rheological parameters were carried out on them at the end of 1, 2, and 3 months, respectively, as done for the fresh SC samples.

2.12 | Microbiological analysis

One gram (1.0 g) of cassava starch based SC was homogenized in 9.0 ml sterile 0.1% peptone water for 30 s (normal speed) to a homogenous suspension, and then, a 10-fold serial dilution in peptone water was carried out.

For total aerobic bacteria count, 1 ml of aliquot from suitable dilutions was plated on Nutrient agar (CM003, Oxoid Ltd, Basingstoke Hants, England) plates, the plates were incubated at a temperature of 37°C for 24 hr. Total plate count (TPC) was enumerated and was expressed as number of colony forming units/g.

2.13 | Data analysis

Analysis of Variance (ANOVA) was used to analyze data obtained and significant effect of independent variables at 5% level was separated using Duncan's Multiple Range test. (SAS version 9.1). Linear regression of sample viscosity with storage time was done using Statistical Package for Social Sciences (SPSS version 21.0) software.

3 | RESULTS AND DISCUSSION

3.1 | Proximate composition of SC from cassava starches

The proximate composition of the fresh SC samples from the different cassava starches is shown in Table 1. The moisture content ranged from 55.46% to 65.07%, with TMS 01/1412 having the highest, while TMS 01/1206 had the lowest. The moisture content observed in this study was higher than that reported by Ashaye et al. (2010) of the range 35.44 and 48.99% and also that of Babajide and Olatunde (2010) who reported 48.80 and 49.79% for corn-cocoyam-based SC. However, the results obtained were similar to that of Eke-Ejiofor and Owuno (2014) for SC from cassava and potato starches. The slight variation in the moisture content of the SC samples might be due to genetic composition of the different cassava roots used in producing the SC. Protein content of the fresh SC samples ranged from 1.49% to 2.18%, with TMS 01/1368 having the highest value while sample 30,572 had the lowest. There was a significant difference between the fat content of the fresh SC samples. Fat content of the fresh SC samples were also similar to the result obtained by Ashaye et al. (2010) on cassava starch (different varieties) based SC. It was reported that fat content in low calorie mayonnaise to be between 30% and 40% (Dudina et al., 1992). The results of this study showed that the SC is of low calorie category and it was lower than the amount (31%) reported by McCance and Widdowson (1987). The ash contents ranged from 0.95% to 1.25%. TMS 01/1371 had a higher value and TMS 98/0581 had the lowest ash content. There was a significant difference ($p < .05$) in the ash contents of the cassava starches. The ash content of the SC samples were slightly lower than the results (1.04%–2.04%) reported by Prescott and Board (1993) for different mayonnaise samples. This may be due to the presence of starch in the SC samples, which differentiates SC from mayonnaise as starch is not among the ingredients for producing mayonnaise. The sugar content of the SC samples ranged from 5.01% to 6.21% with TMS 01/1412 having the highest sugar content and the lowest was recorded by TME 419. The sugar contents of the SC samples showed a significant

TABLE 1 Proximate composition of fresh SC from cassava starches

Sample (%)	Moisture content	Protein	Fat	Ash	Sugar	Starch
TMS 01/1368	60.65 ± 0.01^{b}	2.18 ± 0.00^{a}	26.61 ± 0.01^{b}	0.99 ± 0.02^{e}	5.17 ± 0.01^{f}	12.58 ± 0.03^{a}
TMS 01/1371	60.60 ± 0.01^{b}	2.03 ± 0.13^{b}	24.34 ± 0.02^{d}	1.25 ± 0.02^{a}	6.01 ± 0.01^{c}	11.82 ± 0.03^{f}
TMS 96/1632	65.03 ± 0.06^{a}	1.53 ± 0.00^{d}	16.79 ± 0.01^{a}	0.84.38 ± 0.01^{g}	5.93 ± 0.01^{d}	12.31 ± 0.01^{f}
TMS 01/1412	65.07 ± 0.12^{a}	2.03 ± 0.06^{b}	22.81 ± 0.01^{e}	0.96 ± 0.01^{f}	6.21 ± 0.01^{a}	11.92 ± 0.02^{e}
TMS 01/1206	55.46 ± 0.59^{d}	2.03 ± 0.13^{b}	27.72 ± 0.01^{a}	1.03 ± 0.02^{d}	5.12 ± 0.02^{g}	12.19 ± 0.01^{d}
TMS 30572	60.01 ± 0.01^{c}	1.49 ± 0.06^{d}	25.20 ± 0.01^{c}	1.10 ± 0.02^{c}	6.14 ± 0.01^{b}	12.43 ± 0.03^{b}
TMS 98/0581	65.00 ± 0.01^{a}	1.75 ± 0.00^{c}	18.91 ± 0.01^{f}	0.95 ± 0.00^{f}	5.56 ± 0.01^{e}	11.41 ± 0.01^{g}
TME 419	65.01 ± 0.01^{a}	1.78 ± 0.06^{c}	26.62 ± 0.01^{b}	1.21 ± 0.01^{b}	5.01 ± 0.01^{h}	10.75 ± 0.03^{h}

Note: Mean values having different superscripts within the same column are significantly different ($p < .05$)

difference ($p < .05$). There was also a significant difference ($p < .05$) in the starch contents of the fresh SC samples. The values ranged from 10.75% to 12.58% with TMS 01/1368 having the highest value while TME 419 had the lowest.

3.2 | Chemical composition of fresh SC from cassava starches

Table 2 shows the chemical composition of fresh SC from cassava starches. The pH of the SC ranged from 3.29 to 3.44 with TMS 01/1412 having the highest value and TMS 01/1206 had the lowest value. The pH values obtained in this study were similar to the values obtained by (Radford & Board, 1993). The pH of SC can have a dramatic effect on the structure of the emulsion (Radford & Board, 1993). The pH is an indication of keeping quality of the product. Total solid values ranged from 56.66% to 34.32% with TME 419 having the highest TS while TMS 01/1206 had the lowest. TMS 01/1368 had the highest titratable acidity and the lowest was recorded by sample 30,572. The PV ranged from 0.23 to 0.66 meq/kg with TMS 01/1206 having the highest value while TMS 01/1368 had the lowest. There was a significant difference between the PVs of the cassava starch based SC samples. PV is used to determine the content of reactive oxygen of fat and oil in terms of milli equivalent of oxygen per kg that oxidize KI under condition of test. The oxidation of fats and oils is due to the formation of peroxides, aldehydes, and ketones (Gray & Roobinson, 1997). SC sample made from TMS 01/1206 was observed to give a higher PV among other SC samples. This indicated higher oxidation of its fats and oils compared to other SC samples even though the value is still much lower than the standards for PV (<10 meg/kg) for SC.

3.3 | Color parameters of SC from cassava starches

The result of the color parameters of the SC from cassava starches is presented in Table 3. Values of lightness (L^*) was high in TMS 01/1371(96.87) and the lowest value was recorded in TMS 96/1632 (86.71). The lightness (L^*) of the SC samples was significantly different ($p < .05$). The yellowness (b^*) values ranged between 15.56 and 21.54 with TMS 96/1632 having the highest value and TMS 98/0581 had the lowest. Redness (a^*) ranged between −0.49 and −1.42 with TMS 01/1371 having the highest while TMS 01/1412 had the lowest. Color is one of the most important quality attributes of SC because it is a criterion a consumer uses to select SC brand from the market. The yellowish color of SC is primarily provided by egg yolk carotenoids (Ferial, Abu-Salem, & Azza, 2008). The color results for lightness (L^*) was similar to the findings of Ashaye et al. (2010), SC from TMS 01/1371 showed a higher degree of lightness (L^*) and this could be due to varietal differences because generally, cassava starch produces very clear sauces which are advantageous in many industrial processes (Oyewole & Obieze, 1995).

3.4 | Apparent viscosity of fresh SC from cassava starches

Table 4 shows the apparent viscosity of freshly prepared cassava starches SC. Viscosity of the SC ranged between 2,538.67 and 4,772.00 CP with TMS 01/1368 having the highest, while TMS 01/1206 had the lowest at a speed 30 rpm. There was a significant difference ($p < .05$) in the viscosities of the SC samples. The highest viscosity value was 4,772 centipoise and this was observed at the lowest shear rate (speed and time) exhibiting a thinning property that is the viscosity decreased with increase in shear rate and this implies a pseudoplastic behavior. All the SC samples viscosities exhibited a pseudo plastic behavior (Non Newtonian behavior) as the shear rate increase the viscosity decreases, highest viscosity was observed at lowest shear rate exhibiting a thinning properties. (Morris, 1989). A non-Newtonian fluid is a fluid whose viscosity is variably based on applied stress, their flow properties are not described by a single constant value of viscosity (BahramParvar, Razavi, & Khodaparast, 2010; Rha, 1975). This implies that the viscosities of the SC samples cannot be described by a single viscosity value.

TABLE 2 Chemical composition of fresh SC samples from cassava starches

Samples	pH	Total solids (%)	Total titratable acidity (%)	Peroxide value (meq/kg)
TMS 01/1368	3.31 ± 0.06^{e}	63.25 ± 0.02^{c}	5.76 ± 0.24^{a}	0.23 ± 0.02^{h}
TMS 01/1371	3.43 ± 0.00^{a}	60.67 ± 0.06^{f}	3.24 ± 0.00^{e}	0.28 ± 0.05^{g}
TMS 96/1632	3.42 ± 0.01^{b}	63.32 ± 0.00b	4.67 ± 0.00^{b}	0.31 ± 0.01^{f}
TMS 01/1412	3.44 ± 0.01^{a}	62.44 ± 0.02^{e}	4.28 ± 0.00^{c}	0.61 ± 0.01^{b}
TMS 01/1206	3.29 ± 0.06^{f}	56.66 ± 0.06^{g}	3.24 ± 0.00^{e}	0.66 ± 0.01^{a}
TMS 30572	3.34 ± 0.01^{d}	62.96 ± 0.02^{d}	3.03 ± 0.18^{e}	0.55 ± 0.06^{d}
TMS 98/0581	3.43 ± 0.01^{a}	63.32 ± 0.01^{b}	3.24 ± 0.00^{e}	0.43 ± 0.01^{e}
TME 419	3.38 ± 0.06^{c}	64.32 ± 0.06^{a}	4.04 ± 0.21^{d}	0.57 ± 0.06^{c}

Note: Mean values having different superscripts within the same column are significantly different ($p < .05$)

3.5 | Changes in proximate composition of SC from cassava starches during storage

The proximate composition of the SC samples from cassava starches during storage is shown in Table 5. The moisture content during storage ranged from 50.96% to 65.07%. The moisture content showed no significant difference ($p < .05$) initially during the storage period but there was a slight decrease in the moisture content at the end of the storage period. There was a decrease in the protein content at the end of the storage period. Protein content of the samples decreased significantly ($p < .05$) as the storage time increased. The decrease would have been due to chemical changes that may have taken place during storage of the SC samples. This could lead to an emulsion with low viscosity and lower stability as the protein content reduces (Ferial et al., 2008).

The fat content of all SC samples significantly decreased at the end of the storage period. The fat content decreased at the end of storage probably due to the breakdown of fats and oils to give free fatty acids (Ogbonnaya & Yahaya, 2008). The decrease could also be attributed to lipolytic activities of enzymes, referred to as hydrolytic rancidity, and thereby allowing oxidative enzymes catalyze the oxidation of the oils by atmospheric oxygen and the degraded fatty acids radiation gives rise to volatile substance with objectionable odor and flavor (Ogbonnaya & Yahaya, 2008). Similarly, to fat containing foods, SC is susceptible to spoilage through the autooxidation of unsaturated and polyunsaturated fats and oils (Ogbonnaya & Yahaya, 2008). The ash content also showed a significant decrease at the end of the storage period. The sugar content of TMS 01/1368, TMS 01/1371, and TMS 98/0581 was not significantly different ($p < .05$) after 1 month of storage; but there was significant decrease at the end of the storage period. The starch content of the SC samples ranged from 11.14% to 13.50% and there was significant difference ($p < .05$) in their starch contents at the end of the storage period.

TABLE 3 Color parameters of SC from cassava starches

Samples	*L**	*a**	*b**
TMS 01/1368	88.46 ± 0.34^{cd}	-1.22 ± 0.01^{b}	20.13 ± 0.04^{b}
TMS 01/1371	96.87 ± 1.21^{a}	-1.42 ± 0.01^{c}	20.19 ± 0.32^{b}
TMS 96/1632	86.71 ± 1.29^{d}	-1.17 ± 0.03^{b}	21.54 ± 0.35^{a}
TMS 01/1412	$88.53 \pm 3.19^{b\text{-}d}$	-0.49 ± 0.09^{a}	19.71 ± 0.96^{b}
TMS 01/1206	87.48 ± 0.23^{cd}	-1.23 ± 0.02^{b}	18.62 ± 0.06^{c}
TMS 30572	90.05 ± 1.94^{bc}	-1.35 ± 0.03^{c}	20.61 ± 1.20^{ab}
TMS 98/0581	91.28 ± 0.33^{b}	-1.23 ± 0.08^{b}	15.56 ± 0.19^{d}
TME 419	90.02 ± 0.25^{bc}	-1.22 ± 0.01^{b}	20.07 ± 0.24^{b}

Note: Mean values having different superscripts within the same column are significantly different ($p < .05$)

3.6 | Changes in chemical composition of SC from cassava starches during storage

Figure 1 shows the changes in pH, TS, titratable acidity, and PV of the SC samples during storage. There was a significant decrease ($p < .05$) in the pH content of the SC samples at the end of the storage period. After first and second month of storage, there was no significant difference ($p < .05$) between the SC samples. The pH decrease in SC and this could be due to increase in storage temperature, as the higher the rate of metabolism of sample (sugar), the higher the rate of acid production (Adebayo et al., 2009). At the end of the storage period, there was a significant difference ($p < .05$) in the TS of the SC samples as reflected by decrease in protein, starch, sugar, and fat contents of the SC samples. TTA of the SC samples increased at the end of the storage period probably due to the activity of hydrolytic and oxidative enzymes that may be present in the eggs used (Stefano, 1989). According to Ferial et al. (2008), free fatty acids may be produced by the oxidation of double bonds of unsaturated fatty acid esters. In advanced stages of oxidation, free fatty acids with low molecular weight will develop through the accumulation of acidic cleavage in products and subsequently increase the acid value. This oxidation could have occurred with the aid of oxidative enzymes and the presence of a proportion of atmospheric oxygen in the headspace incorporated into the SC. There was an increase in PV of all SC samples with increase in storage period. These findings were similar to the findings of oils (Ogbonnaya & Yahaya, 2008). According to their findings, PVs of mayonnaise samples increased during storage showing the susceptibility to go rancid with time during storage.

TABLE 4 Apparent viscosity of SC made from cassava starches at different rotational speed

Samples	30 rpm	60 rpm	100 rpm
TMS 01/1368	$4,772.00 \pm 365.20^{a}$	$3,604.33 \pm 795.17^{ab}$	$2,900.00 \pm 504.77^{bc}$
TMS 01/1371	$4,557.00 \pm 1,408.51^{a}$	$4,543.00 \pm 1,087.84^{a}$	$4,323.00 \pm 1,093.23^{a}$
TMS 96/1632	$3,306.67 \pm 227.45^{b}$	$2,480.00 \pm 401.73^{d}$	1999.33 ± 221.63^{cd}
TMS 01/1412	$3,422.20 \pm 180.83^{b}$	$2,253.33 \pm 197.38^{d}$	2068.67 ± 41.49^{cd}
TMS 01/1206	$2,538.67 \pm 294.25^{b}$	$2,106.67 \pm 462.19^{d}$	1904.00 ± 361.75^{d}
TMS 30572	$4,411.33 \pm 254.25^{a}$	$3,391.00 \pm 424.47^{bc}$	$2,660.00 \pm 469.28^{bcd}$
TMS 98/0581	$2,704.00 \pm 410.01^{b}$	1971.33 ± 303.27^{d}	1752.00 ± 198.92^{d}
TME 419	$4,675.33 \pm 129.06^{a}$	$3,722.33 \pm 400.88^{ab}$	$3,008.00 \pm 146.04^{b}$

Note: Mean values having different superscripts within the same column are significantly different ($p < .05$)

TABLE 5 Changes in proximate composition of SC from cassava starches during storage

Time of storage (month)	Starch source (%)	Moisture content	Protein	Fat	Ash	Sugar	Starch
1	TMS 01/1368	60.60^{d}	2.11^{a}	25.82^{c}	0.79^{jk}	5.16^{r}	13.04^{b}
	TMS 01/1371	60.53^{de}	1.92^{c-e}	24.03^{k}	0.94^{g}	5.99^{i}	11.78^{q}
	TMS 96/1632	63.33^{b}	1.49^{jk}	24.11^{a}	0.61^{a}	5.91^{mn}	12.24^{j}
	TMS 01/1412	64.99^{a}	1.96^{cd}	22.39^{o}	0.50^{r}	6.18^{b}	11.84^{p}
	TMS 01/1206	53.31^{i}	1.89^{d-f}	25.66^{d}	0.84^{i}	5.08^{u}	12.10^{l}
	TMS 30572	59.15^{g}	1.41^{kl}	24.92^{f}	0.88^{h}	6.11^{e}	12.38^{h}
	TMS 98/0581	63.33^{b}	1.68^{i}	16.80^{x}	0.71^{m}	5.55^{p}	11.30^{v}
	TME 419	63.31^{b}	1.71^{hi}	24.71^{g}	0.79^{k}	5.98^{i}	12.70^{c}
2	TMS 01/1368	60.59^{d}	1.96^{cd}	24.79^{g}	0.76^{l}	5.14^{s}	12.81^{c}
	TMS 01/1371	60.21^{ef}	1.78^{f-i}	22.89^{l}	0.76^{l}	5.96^{k}	11.62^{s}
	TMS 96/1632	60.00^{f}	1.38^{kl}	14.76^{b}	0.53^{q}	5.89^{k}	12.18^{k}
	TMS 01/1412	64.80^{a}	1.82^{f-h}	20.59^{t}	0.44^{s}	6.16^{c}	11.71^{r}
	TMS 01/1206	51.06^{j}	1.75^{g-i}	20.74^{s}	0.60^{o}	5.05^{v}	12.06^{m}
	TMS 30572	58.92^{g}	1.27^{m}	22.22^{p}	0.82^{j}	6.08^{f}	12.30^{l}
	TMS 98/0581	61.99^{c}	1.53^{j}	15.85^{y}	0.65^{n}	5.51^{q}	11.24^{w}
	TME 419	60.04^{f}	1.49^{jk}	22.18^{p}	0.69^{m}	5.97^{jk}	12.64^{f}
3	TMS 01/1368	60.52^{de}	1.85^{e-g}	24.11^{j}	0.71^{m}	5.12^{t}	12.73^{de}
	TMS 01/1371	60.14^{f}	1.68^{i}	22.60^{n}	0.74^{l}	5.92^{lm}	11.51^{t}
	TMS 96/1632	59.90^{f}	1.34^{lm}	14.00^{c}	0.51^{r}	5.85^{o}	12.11^{l}
	TMS 01/1412	64.74^{a}	1.75^{g-i}	20.01^{v}	0.40^{t}	7.09^{f}	1.61^{s}
	TMS 01/1206	50.96^{j}	1.68^{i}	20.23^{u}	0.58^{p}	5.04^{v}	12.01^{n}
	TMS 30572	58.82^{g}	1.09^{n}	21.89^{q}	0.78^{k}	6.05^{g}	12.25^{j}
	TMS 98/0581	61.81^{c}	1.46^{jk}	15.17^{z}	0.61^{o}	5.49^{q}	11.14^{x}
	TME 419	59.98^{f}	1.42^{j-l}	21.25^{r}	0.69^{m}	5.91^{mn}	12.60^{f}
Std dev		3.73	0.27	3.90	0.21	0.41	0.55
Std error		0.66	0.05	0.69	0.04	0.07	0.10
P of starch source (S)		*	*	*	*	*	*
P of time of storage (T)		*	*	*	*	*	*
P of S × T		*	Ns	*	*	*	*

Note: Mean values having different superscripts within the same column are significantly different ($p < .05$).

*Interactions significant at $p < .05$.

The PVs obtained in this study were less than 10 indicating that the SC samples were relatively stable to rancidity. Pearson (1990) stated that a rancid taste begins to be noticeable when oil has a PV of 10–20. The PVs were seen to increase gradually over the months indicating that SC goes rancid gradually on storage (Finberg, 1995).

3.7 | Changes in color parameters of SC from cassava starches during storage

Figure 2 shows the parameters [Lightness (L^*). Redness (a^*) and Yellowness (b^*)] values of the SC samples during storage. Redness (a^*) of the samples showed an insignificant ($p < .05$) decrease as the storage period increased. There were significant reduction ($p < .05$) in lightness (L^*) and yellowness (b^*) in all the SC samples at the end of the storage period. The primary source of yellow color in SC comes from the egg yolk. Therefore, the oxidation of the carotenoids might have caused the decrease in the yellowness of the samples.

3.8 | Changes in apparent viscosity of SC from cassava starches during storage

Figure 3 shows the viscosity of the SC samples during storage. Viscosities of all the SC samples significantly decreased at the end of the storage period ($p < .05$). As the storage period increased there was significant differences ($p < .05$) between the SC samples. SC was

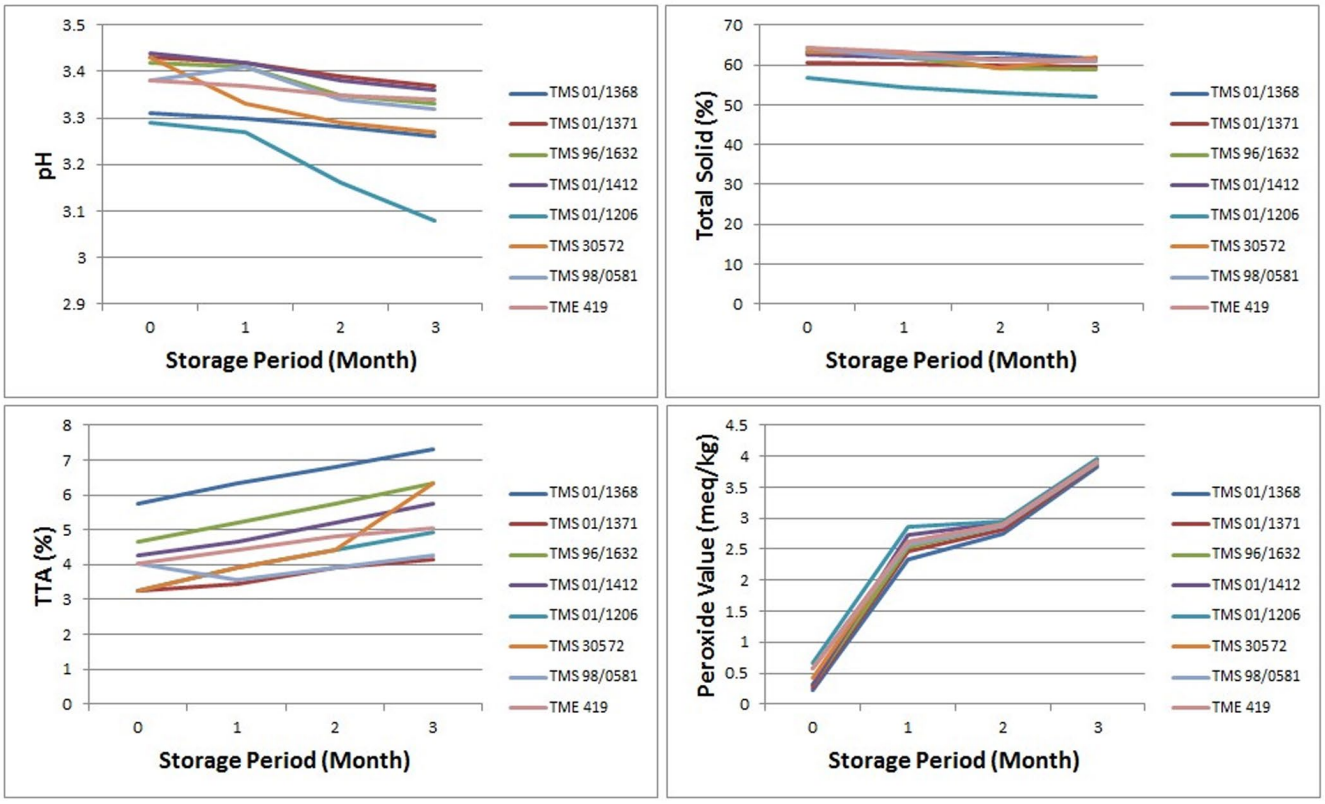


FIGURE 1 Changes in chemical properties of SC from cassava starches during storage

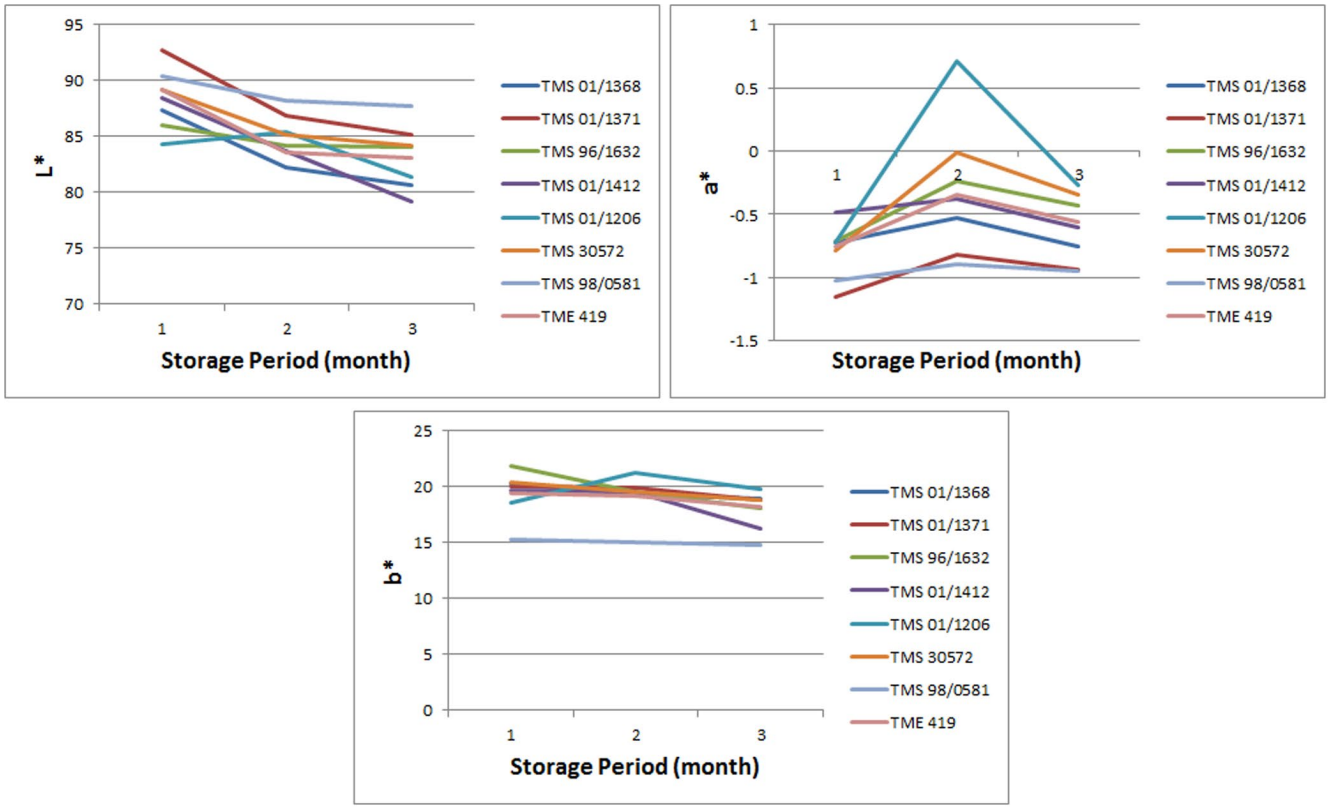


FIGURE 2 Changes in colour parameters of SC from cassava starches during storage

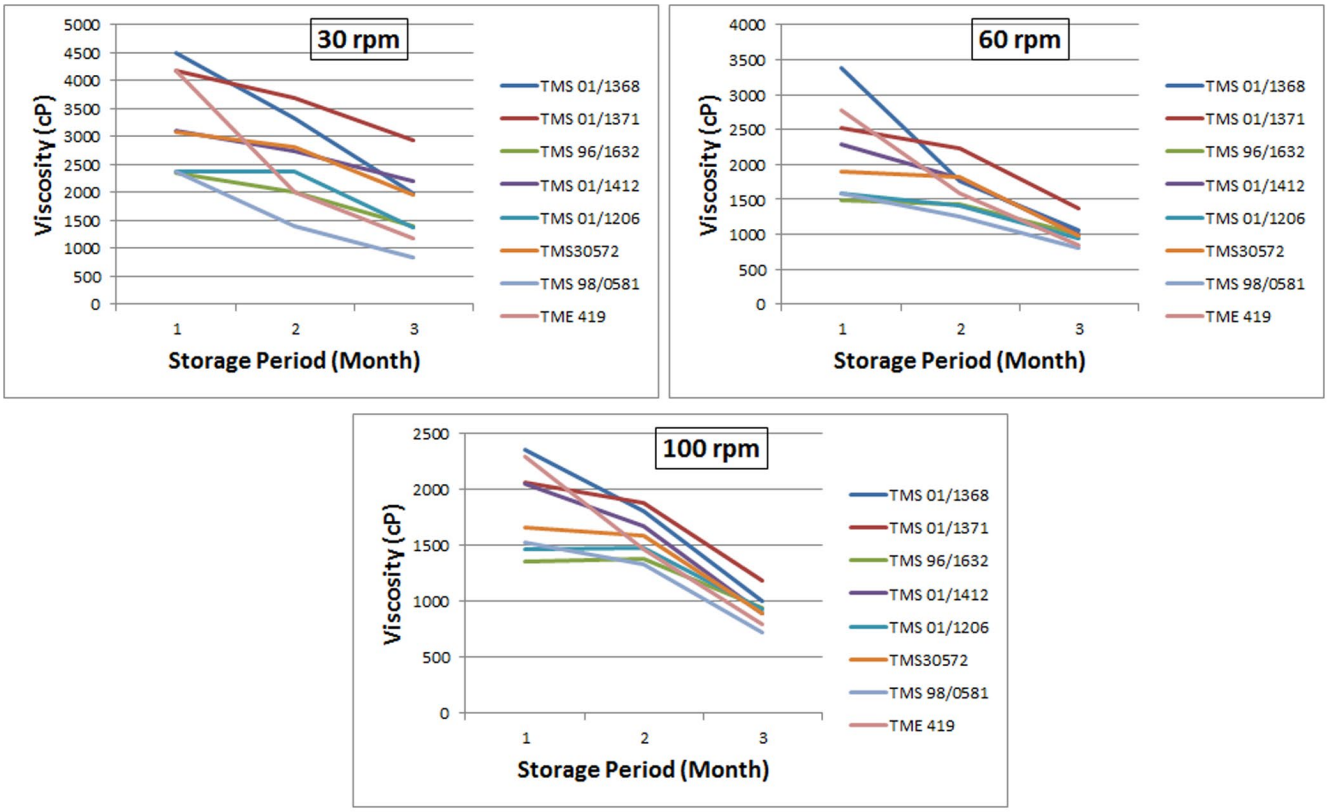


FIGURE 3 Changes in apparent viscosity of SCs from cassava starches during storage

TABLE 6 Microbial load (cfu/g) of SC samples made from cassava starch for fresh and stored samples

Samples	Storage period			
	0	1	2	3
TMS 01/1368	ND	4.45 ± 2.19^{c}	8.25 ± 1.06^{b}	12.05 ± 0.78^{a}
TMS 01/1371	ND	4.50 ± 2.40^{c}	13.25 ± 1.06^{b}	19.50 ± 3.53^{a}
TMS 96/1632	ND	4.90 ± 0.42^{c}	9.00 ± 1.13^{b}	13.30 ± 0.14^{a}
TMS 01/1412	ND	5.80 ± 2.78^{ab}	10.50 ± 3.54^{a}	13.00 ± 1.41^{a}
TMS 01/1206	ND	1.85 ± 0.78^{c}	14.35 ± 0.49^{b}	25.00 ± 1.41^{a}
TMS 30572	ND	6.30 ± 5.23^{ab}	11.75 ± 0.35^{a}	12.25 ± 0.35^{a}
TMS 98/0581	ND	5.50 ± 2.40^{c}	14.50 ± 0.70^{b}	24.50 ± 0.71^{a}
TME 419	ND	5.65 ± 3.32^{a}	16.00 ± 8.49^{a}	15.10 ± 0.14^{a}

Note: Mean values having different superscripts within the same column are significantly different ($p < .05$) ND = Not detected *0 month ($\times 10^2$), 1 month ($\times 10^2$), 2 months ($\times 10^2$), and 3 months ($\times 10^3$)

not continuously sheared during storage, that is the fluid becomes thinner, rather than thicker during storage. Moreover, the shear thinning is a transient behavior. Once the force is removed, the viscosity is lost. Loss of viscosity could have been caused by molecular disintegration resulting from chemical (starch, oil, protein) changes as earlier mentioned. As it was noted that between the cassava varieties, differences were also observed.

Increase in speed were seen to affect all the samples irrespective of the variety, which is similar to the findings of Kahn, Frankel, Snyder, and Potter (1990) for sweetened concentrated dislodge soy beverage.

3.9 | Microbial quality changes in SC from cassava starches during storage

The microbial load of the SC samples made from cassava starch is shown in Table 6. Freshly prepared SC samples had no viable microbial cell. However, the TPC increased with storage period and these were significantly different ($p < .05$) among the SC samples. Spoilage in mayonnaise and salad dressings results from a variety of causes including separation of the emulsion, oxidation, and hydrolysis of the oils by chemical or biological action, and growth of microorganisms that produce gas or off-flavors. Smittle (2000) reported that dressing products are rarely associated

with foodborne illness due to their acidic nature. However, the increase in TPC at the end of the storage period (3 months) reported in this study may be due to the growth of acid tolerant microorganisms such as lactic acid bacteria (Karas et al., 2002). According to the "Microbiological guidelines for ready to eat foods": Center for food safety (May, 2007), the TPC for mayonnaise or salad dressings should be less than 10^4 cfu/g for it to be classified as satisfactory (Class A; CFS, 2015). The values for the TPC from this study are less than 10^4 even after 3 months of storage. This indicates that the SCs samples were relatively stable to microbial growth.

The linear regression of viscosity changes in SC samples made from cassava starch with storage time is shown in Table 7. It was observed from this study that the slope of all the SC samples were negative and this showed that viscosity of the SCs decreased with storage period, which indicates that the textural stability of the SC samples varied significantly ($p < .05$) with TMS 1206 having the most stable flow properties while TMS 1371 had the least.

3.10 | Pearson's linear correlation between the chemical properties, microbial, and viscosity of the SC

Table 8 shows the linear correlation between the properties of SC determined in this study. Apparently, there are very few significant correlations. The most interesting are the correlations between the total plate counts (TPC1 and TPC2) of stored samples and the TS, TTA, and PV of the freshly prepared samples. TS, TTA, and PV are strictly subject of ingredient formulation. The results clearly indicate the preservative ability of the formulation used against the microbial deterioration of the SC. The significant positive correlation between TPC and TS shows that formulation with less solid content could help slow down the proliferation of aerobic organisms in the product during storage. On the contrary, increased acidity could slow down microbial proliferation. Vinegar is the main source of acidulation of SC whereas starch inclusion is the main source total solid in the formulation. This outcome further indicates that subsequent studies to optimize fresh and store sample qualities of cassava starch based SC needs to consider these as important variable to balance their antagonistic effects on the microbial stability of the product. The PV of fresh SC is solely dependent on the quality of oil used. The positive correlation between PV and TCP further establishes the fact that the major microbes that dominate the SC during storage are likely to be the aerobic. Increased peroxidation of the growth medium could have increased oxygen potentials of the medium.

TABLE 7 Linear regression of apparent viscosity changes in SC sample with storage time

Samples	Slope	Intercept	R^2
TMS 01/1368	−623.93	2,951.7	0.9902
TMS 01/1371	−960.97	3,805.7	0.8317
TMS 96/1632	−315.37	1,890.8	0.8668
TMS 01/1412	−389.00	2,257.3	0.8399
TMS 01/1206	−289.00	1879.1	0.8820
TMS 30572	−537.10	2,508.1	0.9092
TMS 98/581	−327.50	1825.5	0.9179
TME 419	−745.37	3,013.0	0.9985

4 | CONCLUSIONS

This study has shown that SC samples produced from starches of eight cassava roots had significantly different physical, chemical, and rheological properties. Viscosities of the SCs were Non-Newtonian and the stored SC samples had significantly different textural stability. Within the 3 months storage period, the SC samples were all chemically and microbiologically stable based on the standards for PV and TPC. The levels of stabilities were based on cassava variety. The most stable SC from textural point of view was derived from a yellow fleshed cassava variety (TMS 1206).

TABLE 8 Correlation between the chemical properties, microbial and viscosity of the SC samples

	pH	TS	TTA	PV	TPC1	TPC2	TPC3	V30	V60	V100
pH	1.000	0.426	−0.123	−0.468	0.546	0.033	−0.032	−0.101	−0.045	0.076
TS		1.000	0.402	−0.382	0.871	−0.239	−0.622	0.468	0.197	0.047
TTA			1.000	−0.611	0.031	−0.713	−0.598	0.319	0.072	−0.038
PV				1.000	−0.254	0.707	0.418	−0.293	−0.247	−0.296
TPC1					1.000	−0.116	−0.579	0.410	0.181	0.085
TPC2						1.000	0.662	−0.169	0.025	0.092
TPC3							1.000	−0.647	−0.346	−0.181
V30								1.000	0.908	0.789
V60									1.000	0.964
V100										1.000

Note: Correlation coefficients in red are significant at $p < .05$, Correlations in dark red are significant at $p < .01$.

Abbreviations: TS, total solid (%); TTA, total titratable acidity (%); PV, peroxide value; TPC1, total plate count after 1 month; TPC2, total plate count after 2 months; TPC3, total plate count after 3 months; V30, viscosity at 30 rpm; V60, viscosity at 60 rpm; V100, viscosity at 100 rpm.

ACKNOWLEDGMENTS

The study is an output of the Cassava Web Innovation work package of the BiomassWeb Project funded by the German Federal Ministry for Education and Research (BMBF) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

The Research Fellowship offered by the International Institute of Tropical Agriculture, Ibadan, Nigeria to the first author is gratefully acknowledged.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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How to cite this article: Adeleke DM, Shittu TA, Abass AB, Awoyale W, Awonorin SO, Eromosele CO. Physicochemical properties, rheology, and storage stability of salad creams made from different cassava starch varieties. *J Food Process Preserv*. 2020;00:e14662. https://doi.org/10.1111/jfpp.14662