



Rheological and Pasting Properties of Flour, Extruded Products and Fresh Samples from Yellow Root Cassava, Orange Fleshed Sweet Potato, Plantain Fortified with *Moringa oleifera* Leaves

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Authors' contributions

This work was carried out in collaboration among all authors. Authors LNU, EAM and NO designed the study. Authors LNU and ANK performed the statistical analysis. Authors LNU, EAM and NO wrote the protocol and first draft of the manuscript. Author LNU managed the analyses of the study. Authors LNU and ANK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: There is complete dependence on wheat flour for baked products, which are imported from other parts as wheat can't grow in Nigeria. Therefore, to reduce the cost of importation, composite flour can be an alternative. Composite flour has some advantages for developing countries such as Nigeria as it reduces the importation of wheat flour and encourages the use of locally available resource for making flour.

Methodology: Orange -fleshed sweet potatoes (OFSP), yellow roots cassava (YRC) were all sourced from National Root Crops Research Institute Umudike (NRCRI), while the plantain and *Moringa oleifera* leaves were gotten from Umuahia market and Michael Okpara University of Agriculture Umudike (MOUUAU) respectively. The samples were processed into flour to form different

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blend ratio. The flour blend constitutes of yellow root cassava, orange fleshed sweet potato and plantain which were fortified with *Moringa oleifera* leaves at constant portion of 5% while the YRC, OFSP and plantain were varied at different concentrations.

Three (3) experiments were conducted, of which experiment 1 is the flour made from the blend of YRC, OFSP, plantain and *moringa oleifera* leave. Sample A, B, C, D, E F, G and H were the composite flour. A consist of 65% YRC, 10% OFSP, 20% Plantain, 5% moringa leaves powder: B consist of 70% YRC, 10% OFSP, 15% Plantain, 5% *moringa* leaves powder: C is 75% YRC, 10% OFSP, 10% Plantain, 5% moringa leaves powder, D is made up of 80% YRC, 5% OFSP, 10% Plantain, 5% moringa leaves powder, E is 85% YRC, 5% OFSP, 5% Plantain, 5% moringa leaves powder, F is 95% and 5% moringa leaves powder, G is 95% plantain and 5% moringa leaves powder and H is 95% and 5% moringa leaves powder respectively. Experiment 2 was the extruded baked snacks from the blend ratio of composite flour and Experiment 3 was the fresh of yellow root cassava, plantain and orange fleshed sweet potatoes analysed on fresh basis.

Results: The breakdown of the extruded baked snacks ranged between (254.72 RVU to 298.54 RVU) from sample P to J. No significant difference ($P > 0.05$) was observed among samples K (271.64 RVU), N (276.64 RVU) and M (279.11 RVU). Peak viscosity values obtained from experiment 1 ranged from 202.31 RVU to 388.68 RVU. There was no significant difference ($P > 0.05$) among the samples A (382.65 RVU), D (382.07 RVU), E (383.07 RVU) and H (384.63 RVU). The holding strength of the composite flour in this study range from 123.16 RVU to 256.62 RVU. The result on experiment 3i. e. fresh of yellow root cassava had the highest peak viscosity of (355.72 RVU), followed by sample R (291.75) and sample S (260.09 RVU) which were the fresh plantain and fresh orange-fleshed sweet potato. Result of trough, indicated that sample Q (117.17 RVU) had the highest trough followed by sample R (83.40 RVU) and S (80.16 RVU). A significant difference was observed on final viscosity within the fresh samples whereby sample Q (394.09 RVU) had the highest score followed by sample R (334.13 RVU) and S (300.63 RVU).

Conclusion: There was no significant difference ($P > 0.05$) within experiment 1, 2 and 3 on peak value, final viscosity, setback, breakdown and peak time while the trough was high in experiment 1 (composite flour) than in experiment 2 and 3. As food, the extrudates with low relative viscosity can easily be eaten by infants while those with high viscosity can only be eaten easily by adults because they tend to be hard and cohesive in texture than samples with low viscosities.

Keywords: Pasting properties; composite flour; extruded products.

1. INTRODUCTION

Viscosity is one of the factors that determine acceptability of processed foods and to know the effect of any treatment on the flour. Also, the knowledge of the rheological properties of extruded products is very important in food extrusion systems because they affect extrudate expansion, texture, and appearance and hydration properties also the thermal and mechanical energy input [1]. Functional and pasting properties of flour and starch products are important for their use in the food industry. For example, the characteristics of products formulated with starch, such as food thickeners and other flour or starch-based products, are greatly influenced by functional and pasting properties [2].

According to Osundahunsi [3], pasting characteristics is necessary to determine the nature of food if it to be in paste form. The ability

of a starch-containing food to form a paste or a gel is one of the principal factors that determine the texture and the quality of that food product. Functional properties of starch such as pasting viscosities influence the textural and gross structure of the food products and they provide information that could be used to determine specific end use applications [4].

Cold viscosity, the viscosity of the paste when cooled to the required temperature, is an important property if the extruded flour/starch will be used as an ingredient in the foods that require cold thickening capacity, like instant soups, creams or sauces while hot paste viscosity is the viscosity of the paste at the start of cooling after heating.

Generally wheat flour is used for the production of baked products such as breads, cakes, buns, doughnuts, and biscuits because of the nature and functional properties of the wheat

flour proteins. But local climatic conditions in tropical countries such as Nigeria are not suitable for profitable wheat production, and consequently it is not grown in the country.

Therefore, Nigeria has been completely dependent on imported wheat for the manufacture of baked products. For this reason, the research focused on composite flours from local crops to replace wheat. Composite flour was defined as a mixture of several flours obtained from roots, tubers, cereals and legumes with or without the addition of wheat flour [5,6]. Composite flours have been used extensively and successfully in the production of baked foods. Some studies were reported on the use of cereal-tuber-legume combination for the production of various products [7,8]. It can be said that the qualities of product depend on the proportion of the individual flour that made up the composite flour [8]. Composite flour had a few advantages for developing countries such as Nigeria as it reduces the importation of wheat flour and encourages the use of domestic agricultural products as flour [9].

Cassava is a major root crop in low- and middle-income Countries [10]. Also, Nigeria, is the world largest cassava (*Manihot esculenta Crantz*) producer and prevalence of other developing countries [11]. Sweet potato ranks the seventh most important food crop in the world and fourth in tropical countries [12]. It is a low input crop, of wide production geography, adaptability to marginal condition, short production cycle, high nutritional value and sensory versatility in terms of flesh colors, taste and texture. Depending on the flesh color, sweet potatoes are rich in β -carotene, anthocyanins, total phenolics, dietary fiber, ascorbic acid, folic acid and minerals [13]. Although sweet potato had many positive attributes and is cheaper than other crops, this abundant resource is still poorly utilized. The development of appealing processed products from composite flour other than wheat flour will play a major role in raising awareness on the potential of the crops. Therefore, the objectives of this study were to analyse the influence of rheological characteristics on composite flour and the flour product from YRC, OFSP, plantain fortified with *moringa oleifera* leave

2. MATERIALS AND METHODS

The material used for this experiment were biofortified cassava roots, order wise known as

yellow root cassava (TMS 07/0593), orange fleshed sweet potato developed by Harvest Plus of National Root Crop Research Institute, *Moringa oleifera* leaves sourced from Michael Okpara University of Agriculture, Umudike and Plantain purchased from the Umuahia main market.

2.1 Experimental Design

The experiment were carried out in three parts. Which are experiments 1, 2 and 3.

In Experiment 1, only the processed flour blends of biofortified cassava (TMS 07/0593), OFSP and plantain fortified with *Moringa oleifera* leaves powder were used. The YRC, OFSP and plantain were peeled, washed, chipped with chipping machine (Adebash Manu. Coy. Manufactured by Addis Engineering. Ltd), oven (Attenzione Cabinet oven drier FE. 5771) dried at 50-60°C at 12% moisture content for 24 hours, milled,(Niji Lukas Nig. Ltd) and then sieved with (US sieve aperture, 0.4mm) to obtain fine flour which was packaged and kept in a safe place for further use. The flour samples were used to form a blend at different concentration which were fortified with *Moringa oleifera* leave. The samples were grouped thus;

Sample A, B, C, D, E F, G and H were the composite flour. Sample A consist of 65% YRC, 10% OFSP, 20% Plantain, 5% *moringa* leaves powder: B consist of 70% YRC, 10% OFSP, 15% Plantain, 5% *moringa* leaves powder: C is 75% YRC, 10% OFSP, 10% Plantain, 5% *moringa* leaves powder, D is made up of 80% YRC, 5% OFSP, 10% Plantain, 5% *moringa* leaves powder, E is 85% YRC, 5% OFSP, 5% Plantain, 5% *moringa* leaves powder, F is 95% and 5% *moringa* leaves powder, G is 95% plantain and 5% *moringa* leaves powder and H is 95% and 5% *moringa* leaves powder respectively.

2.1.1 Experiment 2

Experiment 2 was the extruded baked snacks of the flour blend. The samples are I, J, K, L, M, N, O and P. The formulation of flour blend, extruded snacks were done in the National Root Crops Research Institute processing Unit. The method described by Yiu [14], was used for the production of puffed snacks with little modification. The dough for the extruded blends was first prepared by mixing 100 g of cassava flour, orange fleshed sweet potato flour, unripped

plantain flour and *moringa* leaves powder. Then 1 g of salt and 1g of mixed spices, with 150 ml of water in a bowl. After which the flour was thoroughly mixed to a consistency to obtain a malleable dough at temperature of 37°C. The dough was formed into cylindrical rolls of 5 cm in diameter, after which the cylindrical dough was filled in an extruder which was piped on a greased tray. And was later baked in a hot oven (Gallenkamp Co. Ltd. London, England) at 100°C for 3 minutes to the required moisture content (12%). The baked snacks were allowed to cool on kitchen paper and stored in an air tight containers prior to further use.

2.1.2 Experiment 3

This was the fresh sample of YRC, OFSP and plantain which were named thus; Q, R and S. The samples were homogenised into a puree using a mechanical food blender (Kenwood type).

The pasting properties of the samples were conducted in the Department of Food Science and Technology Laboratory Kadupoly Nigeria.

Pasting properties were carried out on the samples using Rapid Visco- Analyzer (RVA model 3D for windows) (Newport scientific 1998). Flour suspension was prepared by addition of equivalent weight of 3.0 g dry flour to distilled water to make a total of 28.0 g suspension in the RVA sample canister. This was placed centrally into a paddle coupling and was inserted into the RVA machine. The 12 min profile used was seen as it runs on the monitor of a computer to the instrument. The starting temperature was 50°C for 1 min and later headed 50-95°C for 3 min. It was held at 9°C for 3 min before the samples were subsequently cooled to 50°C over a 4 min period. This was followed by a period of 1 min where the temperature was kept at a constant of 50°C. Pasting properties of peak, trough, breakdown, final viscosity, setback, peak time and peak temperature, were determined in triplicate

2.2 Statistical Analysis

The total number of samples was 19 (nineteen). One way ANOVA, least significant were carried out using Statistical Package for Social Scientists (SPSS 13.0) software to determine the significant difference at ($p < 0.05$) between the group means while the means separated using the new

Duncan multiple range test. The mean and least square deviation duplicate analyses were calculated.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Rheological properties of flour blends from yellow root cassava, orange, fleshed sweet potatoes plantain and *Moringa oleifera* leaves powder

The results of the pasting properties for composite flour from Yellow Root Cassava, Orange-fleshed Sweet Potato, and Plantain fortified with *Moringa oleifera* leaves powder are presented in Table 1. The peak viscosity reflects the ability of starch to swell freely before their physical breakdown [15]. Peak viscosity values obtained from this study ranged from 202.31 RVU to 388.68RVU. There was no significant difference ($P > 0.05$) among the samples A (382.65 RVU), D (382.07 RVU), E (383.07 RVU) and H (384.63 RVU). The holding strength of the composite flour in this study range from 123.16 RVU to 256.62 RVU. The pasting temperature of the flour blends ranged from 60.38°C - 59.15°C while no significant differences was observed among samples A (60.18°C), B (60.38°C), C (60.61°C), D (60.21°C), E (60.18°C) and G (60.15°C). The trough (or hot paste viscosity) values of the flour blends ranged between 123.16 RVU to 256.62 RVU with lowest value recorded by sample C and the highest by sample A. There was no significant difference ($P > 0.05$) among samples D (130.65 RVU), E (132.16 RVU), G (130.16 RVU) and H (134.16 RVU). The setback of the flour sample ranged from (268.64 RVU) for sample G to (273.13 RVU) for sample H. The breakdown in viscosity of the flour ranged from 250.64 RVU (sample B) to 281.66 RVU (sample I). Though, there was no significant difference ($P > 0.05$) among the flour samples however, the peak time of the composite flour showed that sample I had the highest value (5.15 minutes), followed by sample B (5.11 minutes) and sample C (5.11 minutes). No significant difference ($P > 0.05$) was observed in samples F (4.93 minutes) and H (4.98 minutes). There was no significant difference ($P < 0.05$) in the pasting temperature among samples A, B, C, D, E and G (60.18°C), (60.38°C), (60.61°C), (60.21°C), (60.18°C) and (60.15°C) while sample F (59.15°C) and H (59.95°C) were significantly the same.

Table 1. Rheological properties of flour blends from yellow root cassava, orange, fleshed sweet potatoes plantain and *Moringa oleifera* leaves powder

Samples	Peak viscosity (RVU)	Trough (RVU)	Final Viscosity (RVU)	Setback (RVU)	Breakdown (RVU)	Pasting Temperature(°C)	Peak Time (min)	Setback Ratio (RVU)	Stability Ratio (RVU)
A	382.65 ^b ± 0.73	256.62 ^a ± 174.63	402.57 ^b ± 0.62	270.65 ^c ± 0.72	250.66 ± 0.78 ^c	60.18 ^{bc} ± 0.01	5.01 ^{bc} ± 0.01	3.013 ^e ± 0.01	0.349 ^b ± 0.00
B	380.12 ^{bc} ± 0.01	129.65 ^d ± 0.69	398.62 ^e ± 0.70	269.64 ^d ± 0.67	250.64 ^c ± 0.67	60.38 ^{ab} ± 0.02	5.11 ^a ± 0.28	3.075 ^b ± 0.01	0.341 ± 0.01
C	346.07 ^c ± 49.59	123.16 ^e ± 0.00	400.52 ^c ± 0.58	276.65 ^a ± 0.65	255.89 ^a ± 1.10	60.61 ^a ± 0.40	5.11 ^a ± 0.01	3.252 ^a ± 0.00	0.359 ^a ± 0.02
D	382.07 ^b ± 1.32	130.65 ^{cd} ± 0.73	399.06 ^d ± 1.27	269.21 ^d ± 0.16	252.66 ^b ± 0.71	60.21 ^b ± 0.02	5.06 ^b ± 0.04	3.054 ^c ± 0.00	0.343 ^d ± 0.00
E	383.07 ^b ± 0.01	132.16 ^{bc} ± 0.00	401.67 ^{bc} ± 0.62	270.14 ^c ± 0.04	251.46 ^{bc} ± 0.46	60.18 ^{bc} ± 0.28	5.02 ^{bc} ± 0.01	3.041 ^d ± 0.00	0.345 ^c ± 0.00
F	388.68 ^a ± 0.74	136.20 ^b ± 0.01	408.67 ^a ± 0.63	272.66 ^b ± 0.71	252.66 ^b ± 0.71	59.15 ^d ± 0.02	4.93 ^d ± 0.01	2.997 ^f ± 0.00	0.350 ^{ab} ± 0.00
G	202.31 ^d ± 1.78	130.16 ^c ± 0.00	399.77 ^d ± 0.47	268.64 ^e ± 0.67	251.14 ^{bc} ± 0.35	60.15 ^{bc} ± 0.57	5.01 ^{bc} ± 0.01	3.072 ^b ± 0.01	0.342 ^d ± 0.01
H	384.63 ^b ± 0.71	134.16 ^b ± 0.00	402.14 ^b ± 0.04	273.13 ^b ± 0.01	252.64 ^b ± 0.74	59.95 ^c ± 0.04	4.98 ± 0.00 ^c	2.998 ^f ± 0.01	0.345 ^c ± 0.01

Mean values are of duplicate and expressed as mean ± SD. Values with the same superscripts in the same column are not significantly different (p>0.05)

YRC = Yellow Root Cassava, OFSP= Orange Fleshed Sweet Potato, A= 65% YRC + 10% OFSP + 20% Plantain + 5% Moringa leaves powder, B = 70% YRC + 10% OFSP + 15% Plantain + 5% Moringa leaves powder, C = 75% YRC + 10% OFSP + 10% Plantain + 5% Moringa leaves powder, D = 80% YRC + 5% OFSP + 10% Plantain + 5% Moringa leaves powder, E = 85% YRC + 5% OFSP + 5% Plantain + 5% Moringa leaves powder, F = 95% YRC + 5% Moringa leaves powder, G = 95% Plantain + 5% Moringa leaf powder, H = 95% OFSP + 5% Moringa leaves powder

3.1.2 Rheological properties of extruded snacks from yellow root cassava, orange fleshed sweet potatoes plantain and *Moringa* leaves powder

The results of the pasting properties of extruded baked snacks are shown in Table 2. The final viscosity of the extruded baked snacks ranged from 389.61 RVU to 401.66 RVU.

The breakdown of the extruded baked snacks ranged between 254.72 RVU to 298.54 RVU. No significant difference ($P > 0.05$) was observed among samples K (271.64 RVU), N (276.64RVU) and M (279.11 RVU). No significant difference ($P > 0.05$) was also observed in pasting temperature among sample I (60.49°C), J (60.31°C), L (60.12°C), M (60.62°C), N (60.62°C) and P (60.64°C) while sample K (65.19°C) had the highest pasting temperature.

The trough from the baked snacks ranged from 84.15 RVU to 138.70 RVU with sample P having the highest while sample J recorded the least. The final viscosity of the extruded baked snacks ranged from 389.61 RVU to 401.66 RVU. The highest was observed in sample P while the least was sample M.

3.1.3 Rheological properties of fresh tuber of yellow root cassava, orange-fleshed sweet potato and plantain

The results of peak viscosity for the fresh samples are shown in Table 3. The result showed that the fresh of yellow root cassava had the highest peak viscosity of (355.72 RVU), followed by sample R (291.75) and sample S (260.09 RVU) .which were the fresh plantain and fresh orange-fleshed sweet potato.

Result of trough, indicated that sample Q (117.17 RVU) had the highest trough followed by sample R (83.40 RVU) and S (80.16 RVU).

A significant difference was observed on final viscosity within the fresh samples whereby sample Q (394.09 RVU) had the highest score followed by sample R (334.13 RVU) and S (300.63 RVU). The set back of the fresh sample ranged from 220.59 RVU to 280.62 RVU which showed that sample Q (fresh sample of YRC) having the highest while sample S (Fresh sample of OFSP) had the least value.

The breakdown of the fresh sample ranged from 171.90 RVU to 240.65 RVU where sample Q had

the highest and the least was observed in sample S.

A significant difference ($P < 0.05$) was observed among the fresh samples both in pasting temperature and the peak time. Sample R had the highest score both in peak time and pasting temperature of 6.96 minutes and 78.18°C followed by sample S and sample Q whose peak time and peak temperature are 6.13 minutes, 5.40 minutes, 66.11°C and 61.72°C respectively.

4. DISCUSSION

4.1 Rheological Properties of Flour Blends from Yellow Root Cassava, Orange, Fleshed Sweet Potatoes Plantain and *Moringa oleifera* Leaves Powder

The peak viscosity increment may be attributed to the high starch content of the cassava, plantain and potato flour used as composite flour causing a high gelatinization and swelling index. In starches, high viscosity is desired for industrial applications in which a high thickening power at high temperature is required (Kim et al. 1995). When starch-based foods are heated in an aqueous environment, they undergo a series of changes known as constituting gelatinization and pasting. These are two of the most important properties that influence quality and aesthetic considerations in the food industry. Since they affect texture and digestibility as well as the end use of starchy foods [16].

Pasting temperature gives an indication of the gelatinization time during processing. It is the temperature at which the first detectable increase in viscosity is measured and is an index characterized by the initial change due to the swelling of starch. Pasting temperature has been reported to relate to water binding capacity, a higher pasting temperature implies higher water binding capacity, higher gelatinization and lower swelling property of starch due to a high degree of association between starch granules [17].

The holding strength of composite flour is the minimum viscosity after the peak, making the starch granules of the flour remain undisrupted when the flour paste is subjected to a holding period of constant temperature, time and shear stress [18]. The holding strength was highest in sample A and lowest in sample C. The flour samples required high gel strength and elasticity

Table 2. Rheological properties of extruded Snacks from yellow root cassava, orange fleshed sweet potatoes plantain and *Moringa oleifera* leaves powder

	Peak (RVU)	Trough (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Breakdown (RVU)	Pasting tempt (C)	Pasting time (min)	Setback Ratio (RVU)	Stability Ratio (RVU)
I	381.66 ^c ± 0.66	100.06 ^d ± 0.08	398.65 ^{bc} ± 0.76	299.46 ^e ± 0.31	281.66 ^c ± 0.64	60.49 ^{cd} ± 0.28	5.15 ^c ± 0.02	3.982 ^d ± 0.00	0.263 ^e ± 0.01
J	382.64 ^b ± 0.74	84.15 ^g ± 2.81	393.15 ^e ± 0.02	312.66 ^c ± 0.71	298.54 ^a ± 0.33	60.31 ^{cd} ± 0.01	5.05 ^{de} ± 0.01	4.589 ^a ± 0.01	0.226 ^h ± 0.01
K	380.17 ^d ± 0.85	89.12 ^f ± 0.01	396.21 ^d ± 0.13	306.16 ^c ± 0.07	271.64 ^f ± 0.67	65.19 ^a ± 6.34	5.11 ^{cd} ± 0.01	4.448 ^b ± 0.01	0.234 ^g ± 0.00
L	381.12 ^{cd} ± 0.01	99.06 ^e ± 0.06	398.61 ^{bc} ± 0.70	399.41 ^a ± 0.42	280.14 ^d ± 0.35	60.12 ^{cd} ± 0.02	5.09 ^{cde} ± 0.01	4.032 ^c ± 0.01	0.259 ^f ± 0.00
M	382.11 ^{bc} ± 0.00	101.69 ^{cd} ± 0.81	389.61 ^f ± 0.71	286.14 ^g ± 0.04	279.11 ^d ± 0.00	60.62 ^c ± 0.01	5.15 ^c ± 0.01	3.816 ^f ± 0.01	0.269 ^d ± 0.01
N	381.61 ^c ± 0.71	103.12 ^c ± 0.01	397.61 ^c ± 2.12	392.66 ^b ± 0.77	276.64 ^e ± 0.74	60.64 ^c ± 0.04	5.04 ^e ± 0.00	3.870 ^e ± 0.00	0.272 ^c ± 0.01
O	378.23 ^e ± 0.04	112.14 ^b ± 1.44	400.10 ^{ab} ± 0.01	290.72 ^f ± 0.86	289.66 ^b ± 0.71	62.04 ^b ± 0.18	5.95 ^a ± 0.02	3.537 ^g ± 0.01	0.299 ^b ± 0.00
P	387.23 ^a ± 0.14	138.70 ^a ± 0.66	401.66 ^a ± 0.45	278.72 ^h ± 0.72	254.72 ^g ± 0.72	60.64 ^c ± 0.35	5.83 ^b ± 0.07	2.910 ^h ± 0.01	0.399 ^a ± 0.01

Mean values are of duplicate and expressed as mean ± SD. Values with the same superscripts in the same column are not significantly different (p>0.05)

YRC = Yellow Root Cassava, OFSP= Orange Fleshed Sweet Potato

I= 65% YRC + 10% OFSP + 20% Plantain + 5% Moringa leaves powder, J = 70% YRC + 10% OFSP + 15% Plantain + 5% Moringaleaves powder, K = 75% YRC + 10% OFSP + 10% Plantain + 5% Moringa leaves powder, L = 80% YRC + 5% OFSP + 10% Plantain + 5% Moringa leaves powder, M = 85% YRC + 5% OFSP + 5% Plantain + 5% Moringa leaves powder, N = 95% YRC + 5% Moringa leaves powder, O= 95% Plantain + 5% Moringa leaves powder, P = 95% OFSP + 5% Moringa leaves powder

Table 3. Rheological properties of fresh tuber of yellow root cassava, orange-fleshed sweet potato and plantain

Samples	Peak (RVU)	Trough (RVU)	Final visco (RVU)	Setback (RVU)	Break down (RVU)	Pasting tempt (°c)	Pasting time(min)	Setback ratio (RVU)	Stability ratio (RVU)
Q	355.72 ^a ±0.86	117.17 ^a ±1.43	394.09 ^a ±6.93	280.62 ^a ±0.70	240.65 ^a ±0.73	61.72 ^c ±0.86	5.40 ^c ±0.01	3.364 ^c ±0.00	0.334 ^a ±0.01
R	291.75 ^b ±0.87	83.40 ^b ±0.30	334.13 ^b ±1.41	250.66 ^b ±0.70	209.62 ^b ±0.69	78.18 ^a ±0.02	6.96 ^a ±0.42	4.006 ^a ±0.00	0.287 ^c ±0.01
S	260.09 ^c ±1.32	80.16 ^c ±0.04	300.63 ^c ±0.71	220.59 ^c ±0.81	171.90 ^c ±1.08	66.11 ^b ±0.28	6.13 ^b ±0.01	3.750 ^b ±0.00	0.308 ^b ±0.00

Mean values are of duplicate and expressed as mean ± SD. Values with the same superscripts in the same column are not significantly different (p>0.05)

YRC = Yellow Root Cassava, OFSP= Orange Fleshed Sweet Potato,

Q = 100% YRC; R = 100% Plantain; S= 100% OFS

for easy mixing and easy extraction from the orifix of the extruder. The result reported by Rosenthal et al. [19] which ranged from 25.07 RVU to 275.90 RVU were similar to the result obtained from this work.

During the holding period of a typical pasting test, the sample is subjected to a period of constant temperature (usually 95°C) and mechanical shear stress. This further disrupts the starch granules and amylose molecules generally leach out into the solution and align in the direction of the shear. A gradual decrease of the paste viscosity during the hold period indicates thermal breakdown of starch and thus, be considered as measure of stability.

Work by Maziya [20] recorded trough ranging from 73.1 RVU to 174.6 RVU which is lower than the result obtained in this research work. Final viscosity is the change in the viscosity after holding cooked starch at 50°C and it represents cooked starch stability. The final viscosity for the flour blend ranged from 398.62 RVU (for sample B) to 408.67 RVU (for sample F). The result from this research was much higher than the result (95.9 RVU to 240.0 RVU) obtained by Mazi et al. [21].

The result of setback from this work is higher than the setback (20.6 RVU to 65.4RVU) as reported by Maziya et al. [20] on flour of cassava, also the work reported by Ajatta et al. [22] ranged from (52.00 RVU- 65.89 RVU). Set back is the phase of the pasting curve after cooling of the starch and this phase involves re-association, retro gradation or re-ordering of starch molecules [23]. High set back is associated with syneresis. This high value of setback is useful if the flour is to be used in domestic products like *fufu*, which requires high viscosity and paste stability at low temperature [24]. It will also be useful during production of extruded snacks.

The result of the breakdown on the flour blends was in agreement from the work by Arisa et al. [25] which ranged from 186.75 RVU to 259.25 RVU but lower than 159.6 RVU to 161.5 RVU as reported by Maziya et al. [20]. The increase in breakdown viscosity in these sample flours implies that the composite flours would not breakdown on low heating and such can find applications in food processing by heating at high viscosity [26].

Breakdown viscosity is the measure of the tendency of swollen starch granules to rupture

when held at high temperatures and continuous shearing [27].

Final viscosity is the ability of starch to form a viscous paste on cooling. The final viscosity increased in all the samples which are higher than the work reported by Ajatta et al. [22] which ranged from (119.81 RVU to 138.61 RVU).

The time at which peak viscosity occurred in minutes is called the peak time [28].The pasting time of the flour blend is the measurement of the cooking time [29]. The peak time from this study was in agreement with the peak time of (5.45-5.76 minutes) reported by Ajatta et al. [22]. However, low peak time is indication of its ability to cook fast. The pasting time and pasting temperature are the same where their values are within a close range.

4.2 Rheological Properties of Extruded Snacks from Yellow Root Cassava, Orange Fleshed Sweet Potatoes Plantain and *Moringa oleifera* Powder

Peak viscosity is often correlated with the final product quality and also provides an indication of the viscous load which are encountered during mixing [30]. The relatively high peak viscosity exhibited by most of the extruded snacks showed that these snacks were easily blinded together during mixing and baking.

The trough from the baked snacks ranged from 84.15 RVU to 138.70 RVU where sample P had the highest and sample J and M recorded the least value.

Final viscosity is the most commonly used parameter to define the quality of a particular sample, as it indicates the ability of the material to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear forces during stirring. The viscosity after cooling to 50°C represents setback or viscosity of cooked paste. It is a stage where retrogradation or re-ordering of starch molecules occurs.

Setback has been correlated with texture of various products. High setback is associated with syneresis or weeping during freeze or thaw cycles. High setback was observed in baked snacks which is an indication of snacks exhibiting lower tendency to undergo retro gradation during freeze/ thaw cycle [31]. While a lower set back

indicated a higher tendency of the flour to undergo retro gradation.

The rate of breakdown depends on the nature of the material, the temperature and degree of mixing and shear applied to the mixture. The ability of a mixture to withstand this heating and shear stress is an important factor for many food processing industries. The pasting time which is a measure of the cooking time was within a very close range where no significant difference ($P > 0.05$) was observed within the samples.

4.3 Rheological Properties of Fresh Tuber of Yellow Root Cassava, Orange-Fleshed Sweet Potato and Plantain

The result of the peak viscosity obtained in this study was in agreement with the values (320.67 RVU) as reported by Maziya-dixon et al. [20] on high quality flour.

Higher setback values are synonymous to reduced dough digestibility (Shittu et al. 2007) [6]. It is a tendency for starch to become firmer with increase resistance to enzymatic attack [32].

The breakdown is the viscosity or stability of the starch gel during cooking. The lower the value, the more stable is the starch gel [33].

The peak viscosity, which is the maximum viscosity developed during or soon after heating portion of the pasting test. Higher swelling index is indicative of higher peak viscosity while higher solubility as a result of starch degradation or dextrinization which results in reduction of paste viscosity Shittu et al.[6].

5. CONCLUSION

Based on the results generated from this study, it is concluded that the rheological properties of flour, extruded product and fresh samples from yellow root cassava, orange fleshed sweet potato and plantain fortified with *moring oleifera* leaves revealed that the pasting property of flour is used in assessing the suitability of its application as functional ingredients in food and other industrial products. The High peak viscosity of experiment 1 contributes to good texture of paste which basically depends on high gel strength. Also, high peak viscosity exhibited by most of the sample snacks indicated that these snacks were easily bind together during mixing and baking and also increase the shelf life.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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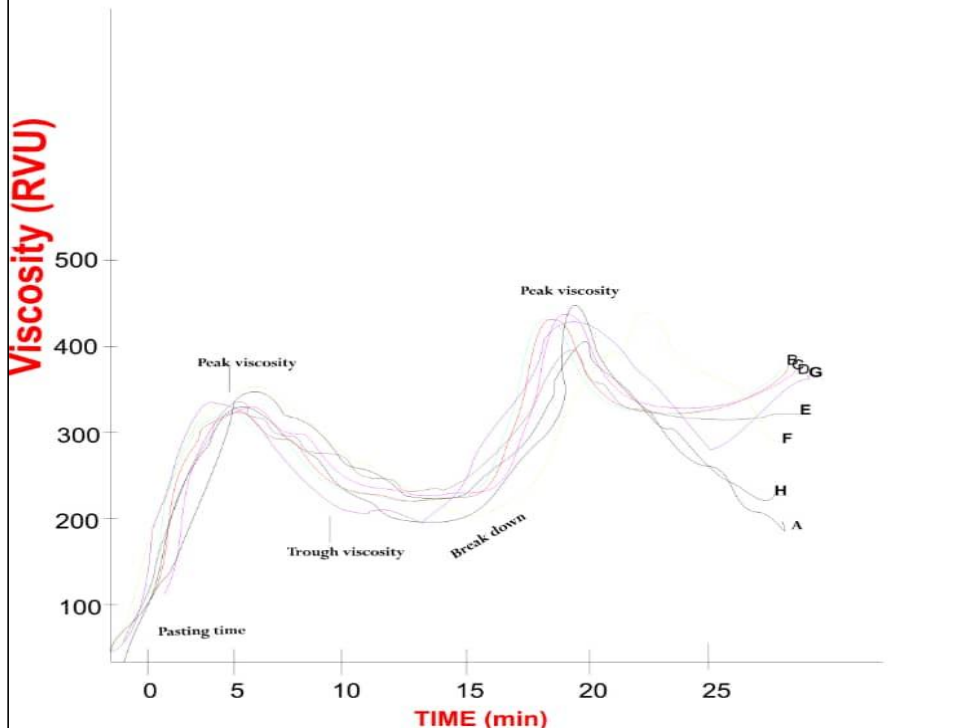
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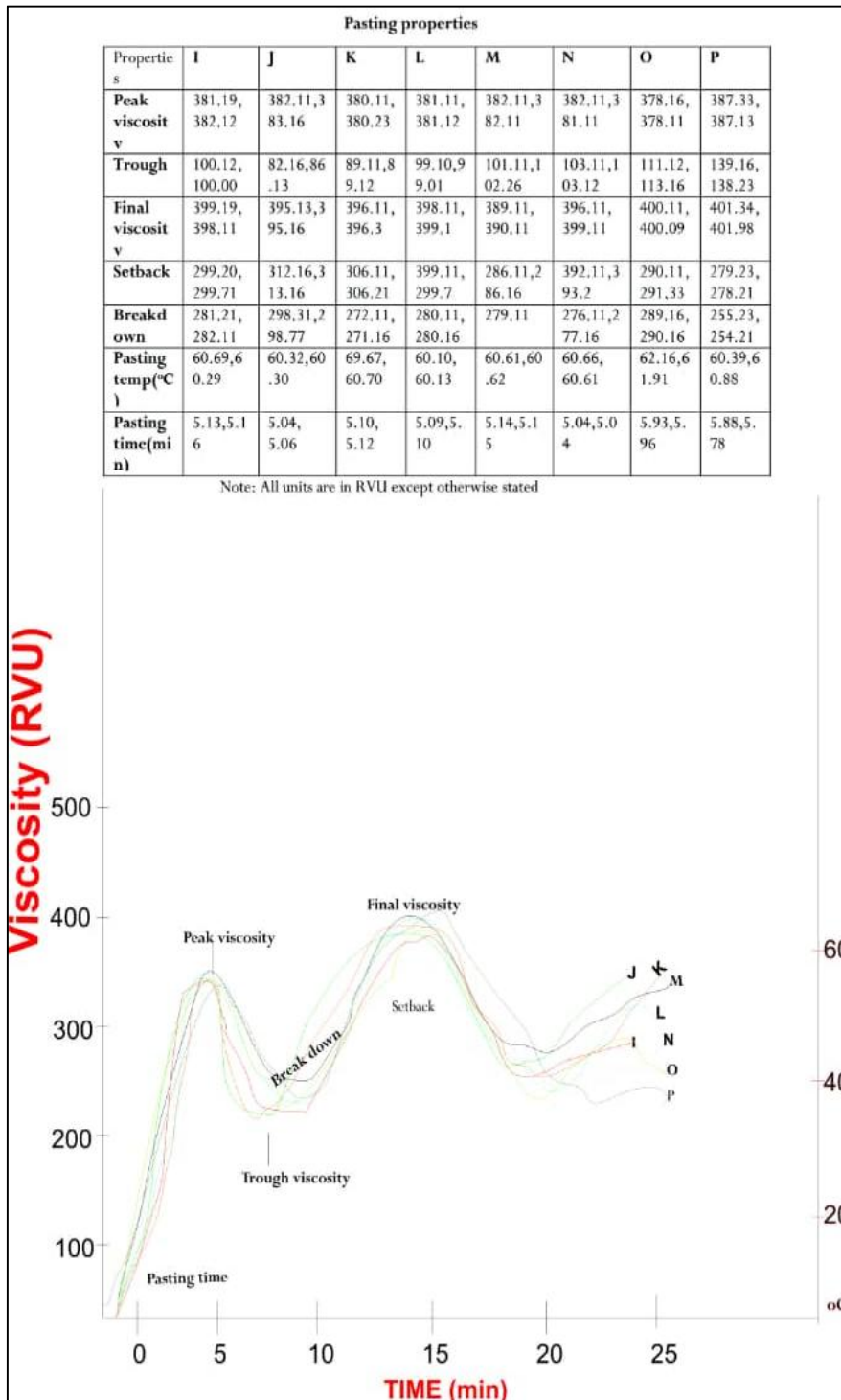
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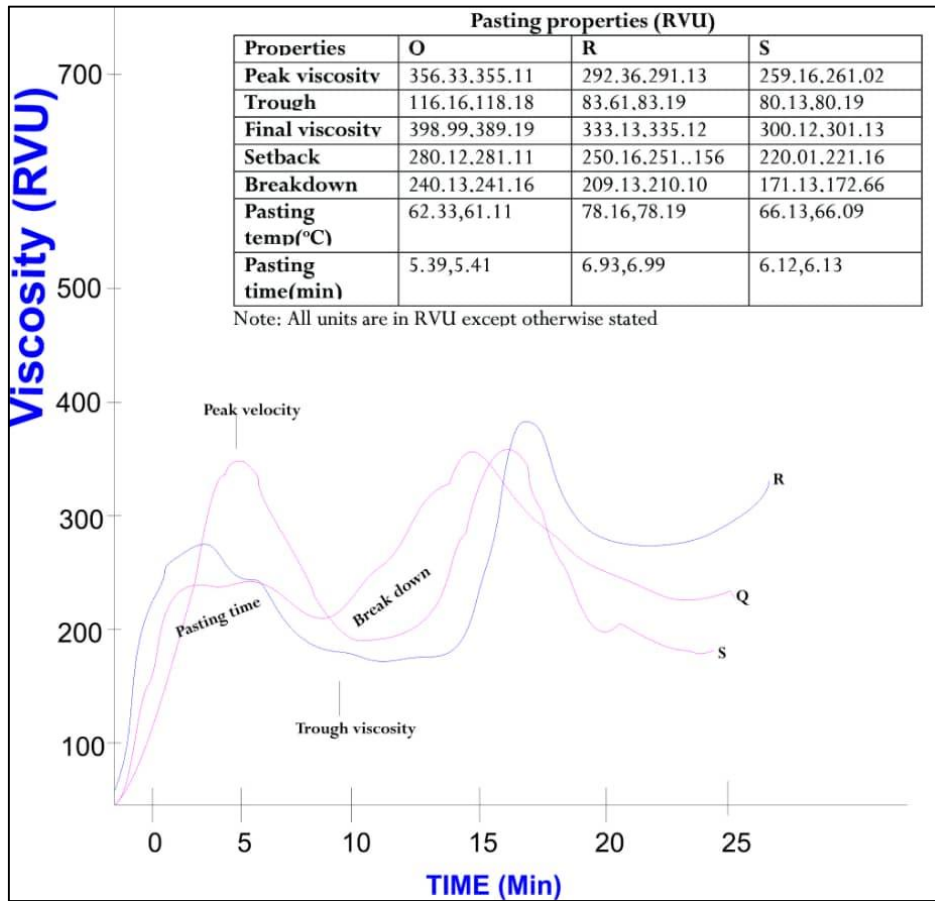
APPENDIX

PASTING PROPERTIES (RVU)								
Properties	A	B	C	D	E	F	G	H
Peak viscosity	383.16, 382.13	380.13,380.10	381.13,311.00	381.13,383.00	383.13,383.00	388.16,389.20	381.23,233.38	385.13,384.13
Trough	133.13, 134.16	130.13,129.16	123.16,123.16	130.13,131.16	132.16,132.16	136.19,136.20	130.16,130.16	134.16,134.16
Final viscosity	402.13, 403.00	399.11,398.13	400.11,400.93	398.16,399.96	401.23,402.11	409.11,408.22	399.43,400.10	402.11,402.16
Setback	270.13, 271.16	269.16,270.11	277.11,276.19	269.32,269.10	270.11,270.16	272.16,273.16	269.11,268.16	273.13,273.12
Breakdown	250.11, 251.21	250.16,251.11	255.11,256.66	252.16,253.16	251.76,251.16	252.16,253.16	251.11,251.16	253.16,252.11
Pasting temp(°C)	60.17,60.19	60.36,60.39	60.33,60.89	60.19,60.22	60.16,60.20	59.16,59.13	60.11,60.19	59.93,59.98
Pasting time(min)	5.01,5.00	5.09,5.13	5.10,5.12	5.03,5.08	5.01,5.02	4.92,4.93	5.00,5.02	4.98,4.98

Note: All units are in RVU except otherwise stated







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