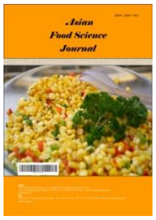

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A Comparative Study on the Viscoelastic Properties of Wheat, Maize and Cassava Flours as Affected by Some Leguminous Seed Flours

E. S. Ukpong[1*], E. F. Okpalanma[1] and R. N. Attaugwu[1]

[1]Department of Food Science and Technology, Madonna University, Akpugo Campus, Enugu State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. The first draft was written by author ESU and authors EFO, RNA had made their inputs before it was finally assembled by the author ESU. All authors read and approved the final manuscript.

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ABSTRACT

The effects of some leguminous seed flour (LSF) on the viscoelastic properties of wheat, maize and cassava flours were investigated. The aim of the work was to evaluate the effect of the LSF on the pasting characteristics of the flours. There were significant differences in the proximate composition of the flours used in this study. Three LSF namely *Brachystegia eurycoma*, *Detarium microcarpum*, and *Mucuna sloanei* flours were used in this study. The LSF were added differently at 0 and 2% to wheat, maize and cassava flours on dry weight bases, the 0% addition served as the control. The viscoelastic properties were determined using Rapid Visco Analyser (RVA). The results showed that the LSF significantly affected the pasting properties of the wheat, maize and cassava flours. The LSF significantly increased ($p>0.05$) the breakdown, final, trough and peak viscosities of the wheat and maize flours. However, the LSF significantly ($p>0.05$) reduced the peak, breakdown and setback viscosities of cassava flour compared to the control.

Keywords: Cassava flour; hydrocolloids; maize flour; pasting properties; wheat flour.

**Corresponding author: Email: ukpongsunday@gmail.com;*

1. INTRODUCTION

Flours from wheat, maize and cassava are used to process numerous food products in different countries of the world. Wheat flour contains a unique protein called gluten and it is used in processing of pasta, noodles, bread, biscuits, cake, buns and other baked goods. Maize and cassava flours do not contain gluten and as such their properties and uses are slightly different from that of wheat flours. Researchers are presently working to modify the properties of the various flours found in their regions to meet the desired quality requirements [1,2-4]. Wheat flour, maize flour and cassava flour as well as many other types of flours exhibit behaviours such as retrogradation, gel syneresis and capacity to exhibit breakdown, whether from high temperature, high shear stress or acid conditions all of which may be undesirable in some applications [5]. These are usually controlled by chemical modifications which are often too expensive [6,7]. An alternative method to chemical modification is the use of hydrocolloids [6,7]. According to Shi and BeMiller [8], hydrocolloids modify flour through the synergistic interaction between the hydrocolloids and the starch in the flour, the intensity of the interaction depends on the type of hydrocolloids used.

Techawipharat [7] defined hydrocolloids as long-chain, high molecular weight polymers, that are usually hydrophilic and has colloidal characteristics, that produce gels in any system that contains water. These compounds which are also called gums have been reported to control the texture and rheology of water-based system throughout the stabilization of foams, suspensions and emulsions [9]. Hydrocolloids are also known to influence the gelatinization of starch [10]. Food processors use hydrocolloids as emulsifiers, stabilizer, gelling agents and thickeners. Its applications in baking industry include the use of psyllium gum, xanthan gum, methylcellulose(MC), hyroxylpropyl methylcellulose (HPMC), locust bean gum, carboxymethyl-cellulose (CMC) and Arabic gum as gluten substitutes in the baking of gluten free bread [11,12], sodium alginate, xanthan gum, HPMC, and K-carrageenan to improve the stability of the dough during proofing [13], while guar gum, locust bean, alginate and HPMC are used as antistaling agents and bread improvers [14]. Hydrocolloids are used to improve texture of products, increase moisture retention, control the pasting characteristics, rheology and retrogradation and maintain the overall storage quality of starch-based food products [8,15-17].

Brachystegia eurycoma, *Detarium microcarpum*, and *Mucuna sloanei* commonly called "*achi*", "*ofor*" and "*ukpo*" respectively by the Igbo people in south-east Nigeria are leguminous plants grown in different areas of semi-arid sub-Saharan and tropical zones of Africa [18]. *B. eurycoma* and *D. microcarpum* belong to the family of flowering plants known as *Leguminosae* and sub-family *Caesalpiniacia* while *M. sloanei* belongs to the *Leguminosae* family and a sub-family of *Papilionacea* of flowering plants [19]. Their seeds are edible and are often processed into flours for use in thickening soups/sauces in some regions of Nigeria [18,20]. It has been reported that about a half of the endosperm of these edible leguminous seeds comprise of hydrocolloids [21-23]. The seed flours of *Brachystegia eurycoma*, *Detarium microcarpum*, and *Mucuna sloanei* are basically used as soup thickeners in Nigeria; their use in other areas of food production has not been fully exploited.

However, it has been reported that the starchy endosperm together with the hydrocolloids in it can control the pasting characteristics, retrogradation, moisture and water mobility in starched-based food systems [8]. Therefore, in this study, these leguminous seed flours which are basically composed of the starchy endosperm and hydrocolloids were added differently to wheat, maize and cassava flours to investigate the pasting characteristics. The objective was to get information on the effect of each of these leguminous seed flours on the viscoelastic properties of wheat, maize and cassava flours. This information will promote the usefulness of these flours.

2. MATERIALS AND METHODS

2.1 Source of Materials

The seeds of *Brachystegia eurycoma*, *Detarium microcarpum*, and *Mucuna sloanei* were obtained in bulk from the farmers in Nkanu in Enugu, Nigeria. Wheat flour (Golden Penny Prime) and maize flour were bought from Ogbette Market, Enugu, Nigeria. High quality cassava flour was prepared from freshly harvested cassava (*Manihot esculenta Crantz*) roots obtained from the farmers in Nkanu in Enugu, Nigeria.

2.2 Processing of the Leguminous Seeds into Flour

Each of the edible leguminous seeds was sorted, soaked in distilled water for 48 h to soften the seed coat. The seed coats were removed using stainless steel knife. The soft gummy endosperms were air dried at ambient temperature (29^0C±0.2) for 4 h and milled in attrition mill. The powdered samples were further air dried at ambient temperature for 96 h, sieved through 0.297 mm mesh size, packaged in clean plastic bottles and stored at ambient temperature (29^0C±0.2) for further use.

2.3 Processing of Cassava Flour

The processing of cassava flour was carried out according to the method described by Ukpong et al. [24]. The freshly harvested cassava roots were first sorted and followed by peeling and washing using potable water. The peeled roots were then grated using mechanical grater, dewatered using screw press, and manually pulverized. The pulverized product was air dried at ambient temperature (29^0C±0.2) for 7 h by spreading thinly on black polyethylene. It was followed by milling to fine powder by the use of attrition milling machine, sieving with 0.297 mm sieve aperture, packaging in clean plastic tins and storing at ambient temperature (29^0C±0.2) until when needed for further use.

2.4 Determination of Proximate Composition of the Flours

It was necessary to ascertain the proximate compositions of the wheat, maize and cassava flours used in this study. The crude protein (Kjeldahl, N x 6.25), fat (Soxhlet extraction with petroleum ether), crude fibre, ash (dry ashing) and moisture (oven drying) contents were determined according to the methods of AOAC [25]. The digestible carbohydrates were calculated by difference. Analyses were carried out in triplicates.

2.5 Determination of pasting Properties

The samples were obtained by adding 2.0% of each of the LSF separately to wheat, maize and cassava flours on dry weight bases. Wheat, maize or cassava flour without the LSF served as the control. The pasting properties were determined in triplicate by use of Rapid Visco Analyzer (RVA_{-4} Model, Newport Scientific Warriewood, Australia) as described by Sim et al. [26]. Three gram of each of the samples was measured into the RVA canister and was followed by addition of 25 ml of distilled water. The sample was introduced into the machine and was followed by a programmed heating and cooling. The sample was held at 50^0C for 1 min, heated from 50°C to 95°C at a constant rate of 12°C/min and then held at 95°C for 2.5 min, cooled to 50°C at the same stirring rate and then held at 50°C for 2 min. Parameters recorded were pasting temperature, peak time, peak viscosity, trough viscosity, final viscosity, breakdown viscosity, and setback viscosity.

2.6 Statistical Analysis

Data were subjected to Analysis of Variance (ANOVA) as described by Steel and Torrie [27]. Significantly different means were separated using Fisher's least significant difference (LSD) procedure at $p>0.05$ level of confidence.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Wheat, Maize and Cassava Flours

The results of the proximate composition of the cassava, maize and wheat flours used in this study are presented in Table 1.The protein content of wheat flour (11.0%) was significant and higher ($p>0.05$) compared to maize flour (7.64%) and cassava flour (1.23%). The reason for this could be because wheat flour has a protein called gluten which is deficient in maize and cassava flours [28,29]. Also, carbohydrate was higher in cassava flour (83.39%) compared to wheat flour (75.05%) and maize flour (75.93%) while fat was higher in maize flour (4.80%) compared to wheat flour (1.51%) and cassava flour (0.96%).The proximate composition of wheat flour in this work is in agreement with the ones reported by Akubor et al. [30] in moisture, carbohydrate, crude fat, crude fibre and crude protein but the result is however different in ash content which was higher in this work. The reason for this could be due to differences in the variety.

The proximate composition of maize flour also agrees with the ones reported by Edema et al. [31] and Islam et al. [32] except in protein which was lower in this work. In cassava flour, the proximate composition is also similar to the results reported by Fakir et al. [33] except in protein which was lower in the present study. The reasons for these disparities in proteins content could be due to variety of the seeds used, agro-ecological condition, or the type of fertilizer used [33].

3.2 Pasting Properties of Wheat- LSF Composite Flours

The result of the pasting properties of the wheat flour substituted with 2.0% of leguminous seed flour (LSF) is as shown in Table 2.The sample that did not contain the LSF (control) had the peak viscosity (PV) of 1384 cP which was significantly increased to 1528, 1672, and 1642 cP in wheat flours that contained *Brachystegia eurycoma*, *Detarium microcarpum*, and *Mucuna sloanei* seed flours respectively.

From the results, it can be suggested that the presence of the LSF increased the peak viscosity (PV) because PV of all the flour samples that contained LSF were higher than and significantly different from the flour without the LSF (control). Among the LSF used, *D. microcarpum* and *M. sloanei* seed flours were the most effective in increasing the PV. The reason for this could be due to the hydrocolloid present in the LSF. Sim et al. [26] found that some hydrocolloids increase the PV of wheat flour. The possible reason for increase in PV could be as a result of the swelling of starch granules due to the effect of wet heat which led to leaching of amylose [34]. Also, there might be an interaction between the starch in the flour and the hydrocolloids in the LSF which made the starch granules to be restricted and tightened resulting in a slow leaching of amylose and hence the increase in viscosity [35].

The trough viscosity (TV) which is also known as hot-paste viscosity is the viscosity when the paste was held at 95^0C and it is the viscosity obtained in the minimum point of the constant temperature phase of the RVA curve. It is an index of how stable is the starch to heat [18,36]. The TV of the control (188.0 cP) was increased to 1106.0, 1086.0 and 1025.5 cP in wheat flours that contained *D. microcarpum*, *M. sloanei* and *B. eurycoma* seed flours respectively. Like in the case of PV, samples that contained *D. microcarpum* and *M. sloanei* seed flours had the highest value of TV. From the results, it is seen that the TV of the flours that contained the LSF were by far higher than that of the control (p>0.05), which indicated that the LSF might have contributed to increase the TV of the system. It can therefore be induced that the LSF made the starch granules in the wheat flour to be more stable to heat than the control. This could be due to the hydrocolloids present in the LSF. Hydrocolloids such as locust bean, psyllium and konjac glucomannan were found to increase the TV of wheat flour [26].

The final viscosity (FV) which is also known as cook-paste viscosity is the viscosity when the paste was cooled to 50^0C. The FV indicates how stable the paste is in actual use as well as its ability to form gel after cooling [18,37]. The FV of the control (1934.0 cP) was increased to 2175.0, 2140.0 and 2082.0cP in wheat flours that contained *D. microcarpum*, *M. sloanei* and *B. eurycoma* seed flours respectively. Again, the FV of flour samples that contained the LSF were higher than and differed significantly from the control (p>0.05) thus indicating the effect of LSF on the FV of the wheat flour. Thus, products from wheat flour where high gel is needed, one way of achieving this could be by substituting 2.0% of the LSF into the wheat flour. The hydrocolloids present in the LSF could be the cause of this increase in FV. Similar increase in FV was reported on wheat flour by locust bean, psyllium and konjac glucomannan [26]. Again, samples that contained *Detarium microcarpum* and *Mucuna sloanei* seed flours had the highest final viscosity.

The setback viscosity (SV) is the final viscosity (FV) minus the trough viscosity (TV). It indicates the behaviour of the starch molecules in the course of heating, cooking and cooling and it also shows how the amylose will retrograde as the starch cools. It has been argued that the swollen starch granules, granule fragments and molecularly dispersed starch molecules can mix together and associate or retrograde as the paste cools [18,36,38]. The SV of all the samples with LSF did not differ significantly from that of the control (p>0.05).

The breakdown viscosity (BV) is peak viscosity (PV) minus the trough viscosity (TV). It measures how the particles of the starch will disintegrate during cooking [36,37,39]. The BV of the control was 496.3 cP. The BV of wheat flour that contained *B. eurycoma* seed flour did not differ significantly from the control (p>0.05). Flours that contained *D. microcarpum* and *M. sloanei* seed flours however, had BV which were higher than and significantly different from the control, the highest was wheat flour that contained *D. microcarpum* (566.5 cP). High BV means that the starch granules were less resistant to heat [6].This effect could be due to the hydrocolloids in the LSF since hydrocolloids such as psyllium, locust bean and konjac gums have been reported to increase in BV of wheat flour [26].

No significant differences (p>0.05) existed in peak time and pasting temperature of wheat flour that contained the LSF and the control. This was in contrast to the report of Sim et al. [26] in which non-ionic gums like psyllium, locust bean, and konjac were found to decrease the pasting temperature while the anionic gums like carboxymethylcellulose (CMC) and sodium alginate increased the pasting temperature in wheat flours. The possible reason for this variation could be because the LSF used in this study also contains fat, starch, fibre, and protein which may produce synergistic or antagonistic effect with the hydrocolloids [13,40].

3.3 Pasting Properties of Cassava-LSF Composite Flour

The results of the pasting properties of cassava flour are presented in Table 3. It was observed that the values of the peak viscosities (PV) of cassava flour (1740-1975 cP) were higher than that of wheat flour (1384-1672 cP). Cassava flour that did not contain the LSF (control) had TV of 1975 cP. This result did not differ significantly from that of cassava flour that contained *M. sloanei* seed flour. However, cassava flour that contained *B. eurycoma* and *D. microcarpum* seed flours significantly reduced the PV (1740-1884 cP) of the cassava flour. This could be because the hydrocolloids in the *B. eurycoma* and *D. microcarpum* seed flours inhibited the swelling ability of the granules of the starch.

Leite et al. [41] however, found opposite effect on cassava starch where xanthan gum, K-carrageenan and sodium carboxymethyl cellulose were found to increase the PV. It is likely that this variation is caused by the fact that the chemical composition of the gums used is different from that of the LSF used in this study.

The trough viscosity (TV) of the control did not differ significantly from cassava flours that contained the LSF at $p>0.05$.This suggested that the LSF did not influence the stability of the starch granules to heat. A similar effect with K-carrageenan on cassava starch had also been previously reported [41]. The final viscosity (FV) was reduced in the presence of the LSF although this reduction was not significant ($p>0.05$). Leite et al. [41] however, reported a significant reduction in FV by cassava starch in the presence of K-carrageenan.

The setback viscosity (SV) of the cassava flour that contained the LSF (412.0-445.5 cP) were all lower than and significantly different from the control (533.5 cP) at $p>0.05$. The reduction of SV by the samples that contained the LSF suggested that retrogradation of starch may be reduced during storage by addition of the LSF [18,38]. Thus, retrogradation of goods produced from cassava flour may be reduced by substituting a portion of the cassava flour with 2.0% of *B. eurycoma, D. microcarpum*, or *M. sloanei* seed flour. This reduction in SV could be due to the presence of hydrocolloids in the LSF. A similar reduction in SV by xanthan gum and K-carrageenan on cassava starch had also been previously reported [41]. It is likely that the reduction in SV occurred because of the interaction between hydrocolloids in the LSF and the amylose molecules of the cassava flour. The result of such an interaction is the formation of intermolecular linkage during cooling which decreases the amount of amylose – amylose interaction which is necessary for retrogradation of starch [41].

The breakdown viscosity of the control (965.5 cP) was reduced to 910.0, 840.0 and 770.5 cP in cassava flour that contained *D. microcarpum*, *M. sloanei* and *B. eurycoma* seed flours respectively which all differed significantly ($p>0.05$) from the control. Among samples that contained LSF, cassava flour that contained *B. eurycoma* seed flour had the least value of BV. The possible reason for the reduction in BV could be because of reduction in the quantity of water available for the starch granules which in turns restrict its swelling [37]. The water content was reduced because of the bonding of hydrophilic group of the fibre of the LSF with the hydrogen bonds of water. Low BV is an indication of paste stability [35,36]. Thus, stability of products produced from cassava flour could be enhanced by adding *B. eurycoma* seed flour. It was observed that the reduction in PV by cassava flours that contained LSF was opposite to that of wheat flour where the LSF were found to increase the PV (Table 2). Rojas et al. [40] and Rosell et al. [13] reported that a particular hydrocolloid can exhibit opposite effect in different systems and therefore the LSF which are good sources of hydrocolloids could also exhibit opposite effect in wheat and cassava flours. It is worthy to note that the nature, structure and quantity of protein, fat, starch and fibre in wheat flour are different from that of the cassava flour and these can affect the pasting properties [13].

The peak time ranges in cassava flour samples (4.24-4.50 min) were lower than that of wheat flour (5.84-6.04 min). The pasting temperature ranges in cassava flour samples (72.55-73.05^{0}C) were also lower than that of wheat flour (87.65-88.10^{0}C). The pasting temperature shows the least temperature needed to cook the paste

Table 1. The proximate composition of the cassava, maize and wheat flours

Flour	Moisture (%)	Protein (%)	Ash (%)	Fibre (%)	Fat (%)	Carbohydrate (%)
Wheat	10.97^{a}±0.34	11.00^{a}±0.09	0.62^{b}±0.05	0.83^{b}±0.03	1.51^{b}±0.05	75.07^{b}±0.36
Maize	8.51^{a}±0.12	7.64^{b}±0.32	1.21^{a}±0.08	1.91^{a}±0.09	4.80^{a}±0.17	75.93^{b}±0.21
Cassava	11.50^{a}±0.31	1.23^{c}±0.08	1.32^{a}±0.07	1.60^{a}±0.03	0.96^{c}±0.02	83.39^{a}±0.35

Mean (n=3)± standard deviation having the same superscript letters within the same column are not significantly different (p > 0.05)

Table 2. Effect of LSF on the pasting properties of wheat flour

Sample	PV (cP)	TV (cP)	BV (cP)	FV (cP)	SV (cP)	PKT (min)	PT (^{0}C)
W	1384.5^{c}±2.8	188.0^{c}±3.2	496.3^{c}±2.2	1934.0^{c}±2.0	1046.0^{a}±1.4	5.84^{a}±0.07	88.05^{a}±0.04
WB	1528.0^{b}±1.9	1028.5^{b}±1.3	499.5^{c}±1.9	2082.0^{b}±2.4	1053.5^{a}±1.8	5.93^{a}±0.05	87.65^{a}±0.06
WD	1672.5^{a}±2.0	1106.0^{a}±2.1	566.5^{a}±2.5	2175.0^{a}±1.7	1069.0^{a}±1.9	6.04^{a}±0.01	88.10^{a}±0.01
WM	1624.0^{a}±2.4	1086.0^{a}±2.7	538.0^{b}±2.1	2140.0^{a}±2.1	1054.0^{a}±1.6	5.93^{a}±0.01	88.05^{a}±0.02

Mean (n=3)± standard deviation having the same superscript letters within the same column are not significantly different (p>0.05). W = wheat flour (control); WB = Wheat flour and 2% Brachystegia eurycoma seed flour; WD = Wheat flour and 2% Detarium microcarpum seed flour; WM = Wheat flour and 2% Mucuna sloanei seed flour; PV= peak viscosity; TV= trough viscosity; BV= breakdown viscosity; FV= final viscosity; SV= setback viscosity; PKT= peak time; PT= pasting temperature

Table 3. Effect of LSF on the pasting properties of cassava flour

Sample	PV (cP)	TV (cP)	BV (cP)	FV (cP)	SV (cP)	PKT (min)	PT (^{0}C)
C	1975.5^{a}±2.1	1010.0^{a}±2.0	965.5^{a}±1.5	1543.5^{a}±1.9	533.5^{a}±1.9	4.24^{c}±0.02	72.98^{a}±0.05
CB	1740.0^{c}±2.3	969.5^{a}±1.8	770.5^{d}±2.0	1415.0^{a}±2.1	445.5^{b}±1.4	4.40^{b}±0.01	73.05^{a}±0.02
CD	1884.5^{b}±2.0	974.5^{a}±1.5	910.0^{b}±1.7	1407.5^{a}±2.0	433.0^{b}±1.6	4.40^{b}±0.00	72.55^{a}±0.03
CM	1910.0^{a}±2.3	1070.0^{a}±2.1	840.0^{c}±1.9	1482.0^{a}±2.0	412.0^{b}±1.9	4.50^{a}±0.01	73.03^{a}±0.01

Mean (n=3)± standard deviation having the same superscript letters within the same column are not significantly different (p > 0.05). C = Cassava flour (control); CB = Cassava flour and 2% Brachystegia eurycoma seed flour; CD = Cassava flour and 2% Detarium microcarpum seed flour; CM = Cassava flour and 2% Mucuna sloanei seed flour; PV= peak viscosity; TV= trough viscosity; BV= breakdown viscosity; FV= final viscosity; SV= setback viscosity; PKT= peak time; PT= pasting temperature

Table 4. Effect of LSF on the pasting properties of maize flour

Sample	PV (cP)	TV (cP)	BV (cP)	FV (cP)	SB (cP)	PKT (min)
M	190.0^{b}±1.8	164.5^{b}±1.3	25.5^{b}±1.1	652.5^{b}±2.0	488.0^{b}±1.1	7.00^{a}±0.01
MB	236.0^{a}±1.3	199.0^{a}±1.4	37.0^{a}±1.0	750.5^{a}±2.4	551.5^{a}±1.9	6.97^{a}±0.01
MD	236.5^{a}±1.5	202.0^{a}±1.0	34.5^{a}±1.3	742.0^{a}±1.9	540.0^{a}±2.0	7.00^{a}±0.00
MM	224.0^{a}±1.0	191.0^{a}±1.5	33.0^{a}±1.3	707.0^{a}±1.7	516.0^{ab}±1.0	7.00^{a}±0.00

Mean (n=3)± standard deviation having the same superscript letters within the same column are not significantly different (p>0.05). M = Maize flour (control); MB = Maize flour and 2% Brachystegia eurycoma seed flour; MD = Maize flour and 2% Detarium microcarpum seed flour; MM = Maize flour and 2% Mucuna sloanei seed flour; PV= peak viscosity; TV= trough viscosity; BV= breakdown viscosity; FV= final viscosity; SV= setback viscosity; PKT= peak time

[37,39]. Like in wheat flour, no significant difference existed between the pasting temperature of cassava flour with or without the LSF at p>0.05. However, unlike in wheat flour, the peak time in cassava flour samples were found to be higher (p>0.05) in samples containing LSF (4.40-4.50 min) compared to the control (4.24 min), the highest was with *M. sloanei* seed flour (4.50 min). It seems that the LSF delayed the time it took the sample to reach the pasting temperature by thickening the granules which resulted in more cooking time.

3.4 Pasting Properties of Maize- LSF Composite Flour

The results of the pasting properties of maize flour substituted with 2.0% of LSF are shown in Table 4.The PV of maize flour without the LSF (control) was 190.0 cP which significantly increased to 224.0, 236.0 and 236.5 cP in maize flours that contained *M. sloanei, B. eurycoma* and *D. microcarpum* seed flours respectively. Like in wheat flour, the LSF increased PV of the maize flour because all the maize flour samples containing LSF were higher than and significantly different from the control at p>0.05.

This shows that the LSF enhanced the swelling of the starch granules to a higher capacity [37]. However, it was observed that the values of PV with or without LSF in maize flour were by far lower than that of wheat flour (1384-1672 cP) and cassava flour (1740-1975 cP) earlier reported in this work. The reason for this could be because the maize flour had higher composition of fats and fibre (Table 1) which are reported to affect the viscosity by competing with the starch granules in the flour for the absorption of water which in turns might interfere with the swelling of the starch granules [37].

The values of trough viscosity (TV) were also lower than that for wheat flour (Table 2) and cassava flour (Table 3) and like in wheat flour, the TV of the control (164.5 cP) was significantly increased (p>0.05) in maize flour containing the LSF (191.0-202.0 cP). This suggests that the LSF enhanced the starch granules and made them more stable to heat [36]. Furthermore, the LSF increased the setback viscosity (SV) of maize flour (516.0-551.5 cP) compared to the control (488.0 cP), indicating that retrogradation behaviour might be enhanced in the presence of the LSF. Also, the LSF increased the breakdown viscosity (BV) of the maize flour, indicating that the LSF might enhance the starch granules and made them less resistant to heat [6]. Generally, the values of BV of maize flour (25.5-37.0 cP) were lower compared to that of wheat flour (496.3-566.5 cP) and cassava flour (770.5-965.5 cP) as earlier reported. This could be due to the higher content of fibre and fat in maize flour (Table 1) which might have obstructed starch granules swelling resulting in lowering of the PV and a corresponding decrease in BV [37].

No significant effect existed between the peak time of maize flour that contained the LSF and the control. However, the peak time was higher here (6.97-7.00 min) than that of wheat flour (5.84-6.04 min) and cassava flour (4.24-4.50 min) earlier reported in this work. A possible explanation to this could be because the high content of fat and fibre in the maize flour resulted in increased solute components of the system and hence more cooking time.

4. CONCLUSION

The work showed that the addition of leguminous seed flours affected the viscoelastic properties of the wheat, cassava and maize flours. The leguminous seed flour increased the breakdown, peak, final and trough viscosities of the wheat flour. They also increased the peak, trough, final, breakdown and setback viscosities of the maize flour. However, they reduced the setback, breakdown and peak viscosities of cassava flour. It can be inferred from this work that addition of leguminous seed flour can enhance high gel formation during cooking and cooling in wheat and maize flours. They can also enhance paste stability to heat and reduce retrogradation in cassava flour. Thus, the addition of the leguminous seed flours modifies the pasting properties of the wheat, maize and cassava flour. This can be useful in products development.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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