Journal of Technology & Socio-Economic Development
https://zenodo.org/deposit/new?c=ciris
ISSN Print: 2223-9227
ISSN Online: 2616-9614
DOI: 10.5281/zenodo.8122248

Pasting Behaviour of Cassava and Maize Flour Containing Gum Arabic from *Acacia senegal* var. *kerensis*

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Published online: 6th July, 2023

Abstract
The application of flour in food production and in the industry depends on various properties including texture and pasting. These properties of flour are influenced by their interaction with food hydrocolloids, especially gums. In the current study, the influence of replacing gum Arabic (GA) from *Acacia senegal* var. *kerensis* (Kenyan variety) at the levels of 0 %, 2%, 4%, 6% and 8% on the pasting behaviour of maize and cassava flour was investigated. Resistance to stirring was recorded as viscosity in Brabender Units (BU). Substitution of cassava and maize flour by GA reduced significantly ($p < 0.05$) the peak viscosity, final viscosity and setback viscosity for both flour pastes. Even though the breakdown viscosity of cassava flour pastes reduced significantly with increasing levels of the gum, maize flour pastes recorded a zero breakdown as the substitution level increased from 2 % to 8%. Pasting temperature (64.15-63.55°C) and (87.1-84.9°C) decreased with increasing gum content for cassava and maize flour pastes respectively though no significant difference was observed at lower levels and the control sample. Maize flour depicted low peak viscosity values (157 BU at 0% GA to 73 BU at 8% GA) as compared to cassava flour (645 BU at 0% GA to 384 BU at 8% GA). A significant decrease in final and setback viscosities were observed in both flour with the addition of GA. Maize flour did not however display significant difference in breakdown viscosity values as opposed to cassava flour which exhibited significant reduction in breakdown viscosity with increasing amount of gum. These results demonstrate that GA from *A. senegal* var. *kerensis* (Kenyan variety) could be considered in the preparation of various food products from cassava and maize flour to enhance binding potential, stability as well as preventing retrogradation.

Key words: Cassava flour, maize flour, gum Arabic, pasting behaviour, viscosity

1. Introduction

Maize (*Zea mays*) is the most essential food commodity in Kenya that accounts for about 40 percent of daily calories and is cultivated across extensive wide-ranging lands (SSEA, 2019). The common maize preparations in Kenya utilize either the grain or flour (the ground grain) whereas for cassava the tuber or flour is usually used. Cassava (*Manihot esculenta Crantz*) grows in varied zones characterized by similar climatic conditions. Githunguri *et al.* (2017) highlighted that this root crop is the second most essential food after the Irish potato in Kenya and is cultivated broadly in Western and Coastal regions of the country. Cassava flour and starch has been reported to comprise the main component of the cassava root hence plays a very critical role in the application of cassava as a food and as an industrial crop (Nuwamanya *et al.,* 2010).

Starch granules in flour normally become hydrated and usually swell when subjected to heat in presence of water leading to the formation of a paste. The afore mentioned process is referred to as pasting and it comprises of starch granule structure disintegration to from crystallites and finally deformation by the unwinding of the hydrogen bonds. According to Wang *et al.* (2015) the functional properties of flour/starch are determined by the changes that involves water uptake, granule swelling as well as the formation of a viscoelastic paste during heating and partial re-association of disaggregated paste in form of a gel a process known as retrogradation. Cassava flour has been reported to gain popularity significantly and particularly has been used to substitute wheat flour in bread making and other baking processes because of its special quality attributes (Dudu *et al.*, 2019). However, these authors have highlighted technological challenges with regard to the application of cassava flour in food processing especially in bakery production. For decades hydrocolloids particularly gums have been employed for enhancement of the flour properties (Chhabra *et al.,* 2018).

Research studies have also shown that the viscometric and textural properties in food products have been modified by the addition of additives especially hydrocolloids, furthermore these properties are the most paramount as they ultimately influence the sensory attributes as well as the stability of the food product during storage (Saha and Bhattachrya, 2010; Mahmood *et al.,* 2017). Previous study also revealed that use of hydrocolloids was the best substitute to chemical methods of modification (Alam *et al.,* 2009). Therefore, current consumer demand for natural ingredients has resulted in growing interest in the use of gums to improve native flour functionality.

Problem Statement

Maize and cassava flour possess a great ability for utilization in various food formulations however they lack vital qualities *vis-à-vis* viscoelastic behaviour as well as structural stability hence limiting their applications. More frequently starchy foods are subjected to certain degree of heat prior to consumption followed by cooling when they were not consumed and this happens many times. Such heating and cooling cycles do increase the rate of starch deterioration leading to staling of these foods which can cause reduced shelf-life as well as reduced consumer acceptance. Due to growing market demand for economical, safe and natural food ingredients, the use of gums becomes crucial with respect to the above challenges due to their viscoelastic nature and has also been shown to improve stability, texture, reduce cost as well as other pertinent parameters associated with native flours and starches.

Literature Review and Conceptual Framework

Hydrocolloids can be utilized for the formulation of various gluten free products where it tends to mimic the function of gluten owing to their viscoelastic nature (Sahni *et al.,* 2020). Studies have shown that hydrocolloid addition influences certain characteristics of flours and starch such as viscosity, retrogradation of starch dispersions as well as syneresis of starch gels. Correspondingly, these parameters are determined by rheological, gelling, syneresis and textual properties of flour and starches (Mahmood *et al.,* 2017; Chhabra *et al.,* 2018; Sahni *et al.,* 2020).

Gum Arabic (GA) is a dried, gummy exudate derived from Acacia trees and has been reported to be rich in non-viscous soluble fiber (Patel and Goyal, 2015). According to this study, GA is a commonly used food hydrocolloid owing to its high solubility, low viscosity, low toxicity and binding properties. The gum has been shown to be beneficial to baked products with regards to processing, appearance and storage which has been attributed to its control of moisture as well as film forming properties. Alam *et al.* (2009) studied the influence of different gums on wheat flour and revealed that GA as compared to other gums had a significant reduction of the peak viscosity and breakdown during heating resulting to increased stability during cooking. Furthermore, their results demonstrated that starch deterioration could be reduced at the onset of storage by the addition of hydrocolloids.

Application of corn and cassava flour in new product establishment and food preparations is directed by ultimate use properties such as the conformation, texture as well as pasting.

Pasting behaviour of any flour is important for the characterization of its starch for its commercial utilization due to the peculiar features it imparts to the food by virtue of its polymers i.e the amylose and amylopectin contents (Rojas *et al.,* 1999; Sahni *et al.,* 2020). However, the incorporation of hydrocolloids can result in interaction of the hydrocolloids with the hydroxyl bonds of starch and change in its pasting properties (Fu *et al.,* 2015). According to Chhabra *et al.* (2018) some gums for e.g xanthan and guar gum could be utilized for the establishment of products from maize flour to specifically improve the texture, adhesiveness as well as the viscosity of the paste. Researchers have shown the potential of high-quality cassava flour to improve its application in bread production when substituted up to 18% with hydrocolloid at 2% level without influencing its overall acceptability. The textural behaviour of starch gels from cereals and root crops especially cassava flour has been shown to produce substantial amounts of starch since it has a key role in the classification of sensory attributes and food quality (Lu *et al.,* 2020). Reports have also indicated that as a result of high rate of retrogradation and syneresis, cassava flour and starch in native form has limited application in refrigerated and frozen food systems (Seetapan *et al.,* 2015).

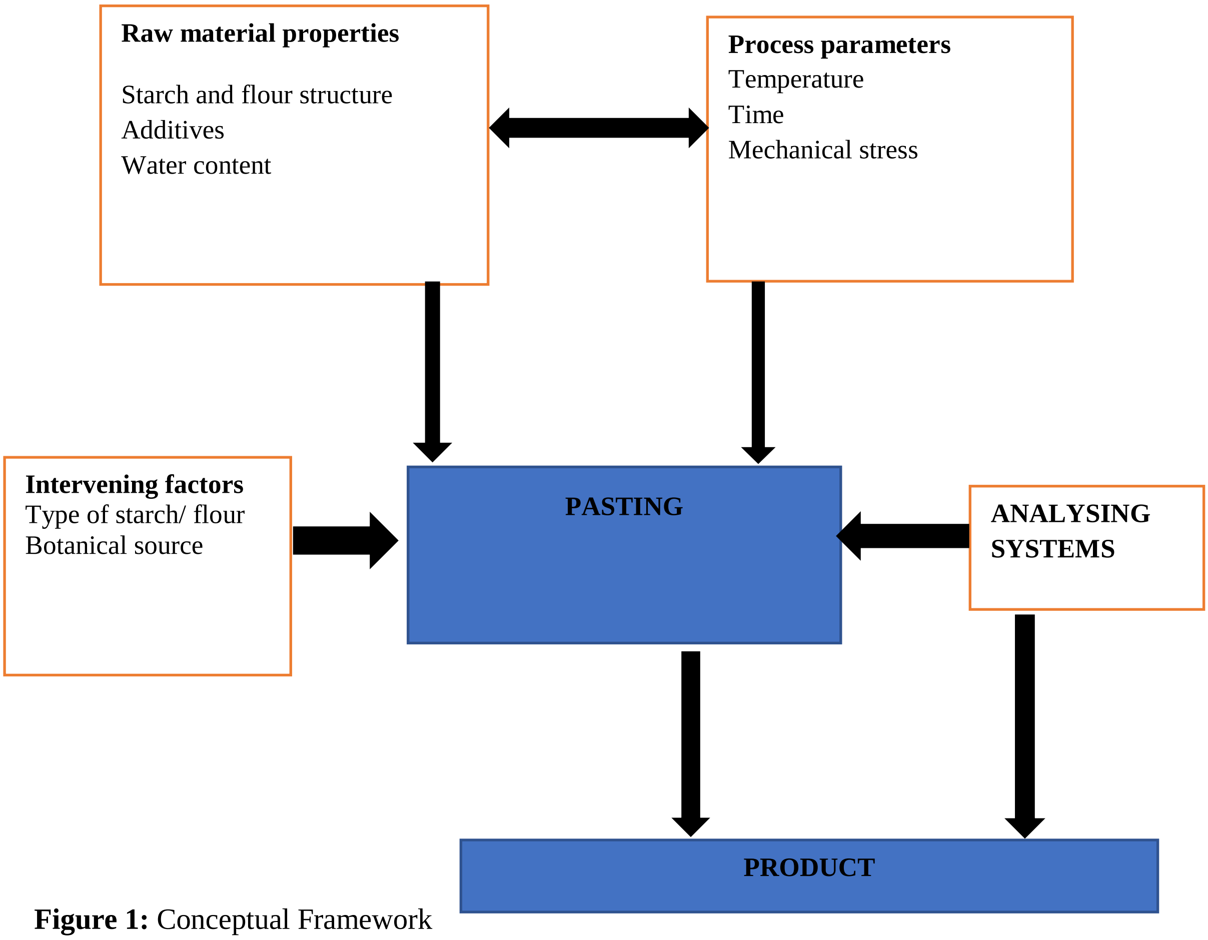

Figure 1: Conceptual Framework

Research Objectives and Purpose

The main aim of this research was to determine the influence of adding GA from *A. senegal* var. *kerensis*, the Kenyan variety, on the functionality of cassava and corn flour. Functionality of the flour-gum blend was studied by evaluating the effect of different concentrations on the pasting characteristics. Data generated from this research provides enlightenment on the potential use of this gum in food production and processing to yield good functionality to the various food systems.

2. Materials and Methods

2.1 Materials

Cassava flour was purchased from Mhogo Foods Limited, Nairobi, Kenya while maize flour was sourced from a local supermarket. Gum Arabic from *A. senegal* var. *kerensis* was procured from Kennect Ltd, Kenya.

2.2. Preparation of blends

The gum was milled into fine particles and then stored in thermopak containers with proper sealing prior to the analyses. The gum Arabic was added to the corn and cassava flour by substitution in dry weight basis (g/g). The flour blends were prepared by inclusion of gum Arabic at 0, 2, 4, 6 and 8 % levels while native flour (0% GA) was used as a control, followed by careful transferring of the respective blends in a round bottomed flask for thorough mixing. The moisture content of each sample that is flour alone (control) and the various concentrations were measured using a rapid moisture meter prior to analysis.

2.3 Pasting properties

Pasting behaviour of the flour were analyzed using a Brabender Viscograph at 85 rpm and 700 cmg torque as described by Onyango (2014). Briefly, slurries made up of 40g flour and flour - gum mixture and 420 ml distilled water added into the Viscograph-E canister. The slurry was heated from 30°C to 93°C at a rate of 1.5 °C/min; held at 93°C for 15min; cooled to 30°C at 1.5°C/min and finally held at 30°C for 15 min. Resistance to stirring was recorded as viscosity in Brabender Units (BU). The pasting temperature (°C), peak, breakdown, setback and final viscosity were determined. All the determinations were done in triplicate.

2.4 Statistical analysis

The data obtained was analyzed using analysis of variance (ANOVA) to determine if the different concentrations of gum Arabic had an influence on pasting properties of cassava and maize flour blends were significantly different. Tukeys honestly significant difference (HSD) test was performed particularly for *post hoc* multiple comparisons and significance was considered at P value < 0.05.

3. Results and Discussion

Effect of addition of gum Arabic on pasting behaviour of the flour

The pasting behaviors of the maize and cassava flour and their respective blends are as shown in **Figure 1** while the overall effect of gum Arabic on the pasting parameters of the flours is listed in **Table 1.** The higher pasting viscosities and a lower pasting temperature displayed by cassava flour as compared to corn /maize flour can be ascribed to low amylose starch content of the former thus less restriction to swelling of the granules upon heating. This observation is very well supported by BeMiller and Whistler (2009) and Ai *et al.* (2013). Both studies linked the higher-pasting temperature and a lower peak-viscosity displayed by starches consisting of larger amylose-content, particularly with the presence of lipids, to the fact that amylose restricts swelling of starch granules during heating and shearing. The effect of GA replacement (0%, 2%, 4%, 6% and 8 %) on pasting properties of cassava and maize flour is presented in **Table 2**.

Table 1. Overall effect of gum Arabic on the pasting properties of cassava and corn flour

Material	OT (°C)	PV (BU)	FV (BU)	Bd (BU)	Setback (BU)
CaF	63.92±0.07[b]	502.70±1.63[a]	383.10±2.77[a]	320.90±4.15[a]	201.10±6.51[b]
CF	86.10±0.28[a]	106.60±0.14[b]	293.60±2.95[b]	1.60±0.12[b]	207.70±5.49[a]

Key: OT= Onset Temperature; PV= Peak Viscosity; FV= Final Viscosity; Bd= Breakdown; CaF= cassava flour; CF= Corn flour. Means with the same letter along the column are not significantly different

Table 2. Pasting profile of cassava and maize flour pasted with different levels of gum Arabic

Flour	Gum level	OTP	PV (BU)	FV (BU)	BD (BU)	SB (BU)
Cassava	0.0%	64.15±0.05[a]	645.00±7.00[a]	446.00±1.00[a]	426.00±2.00[a]	232.00±4.50[a]
	2.0%	64.10±0.00[a]	566.50±1.50[b]	400.50±1.50[ab]	372.00±0.00[b]	209.50±0.50[ab]
	4.0%	63.95±0.05[a]	494.50±7.50[c]	375.00±7.00[b]	318.00±3.00[c]	198.00±2.00[b]
	6.0%	63.95±0.05[ab]	424.00±4.00[d]	355.00±7.00[bc]	262.00±4.00[d]	189.50±6.50[bc]
	8.0%	63.55±0.05[b]	383.50±1.50[e]	339.00±9.00[c]	262.00±5.50[e]	189.50±3.00[c]
Corn	0.0%	87.10±0.20[a]	157.00±5.00[a]	407.00±5.00[a]	7.50±3.50[a]	285.50±1.50[a]
	2.0%	86.75±0.25[a]	123.50±1.50[b]	335.00±1.00[b]	0.50±0.50[b]	234.00±1.00[b]
	4.0%	86.25±0.15[ab]	96.00±1.00[c]	267.00±5.00[c]	0.00±0.00[b]	188.00±5.00[c]
	6.0%	85.50±0.20[b]	83.50±0.50[cd]	237.00±6.00[cd]	0.00±0.00[b]	171.50±1.50[cd]
	8.0%	84.90±0.10[b]	73.00±1.00[d]	222.00±3.00[d]	0.00±0.00[b]	159.50±2.50[d]

OTP, onset pasting temperature; **PV**, peak viscosity; **FV**, final viscosity; **BD**, breakdown; **SB**, setback; **BU**, brabender units. Means with the same letter along the column within each flour type are not significantly different at $p < 0.05$

Onset pasting temperature

The addition of GA decreased marginally the onset pasting temperature in both corn and cassava flour **(Table 2 and Figure 2)**. This suggests that the gum might have caused a delay in granule swelling. The slight decrease in pasting temperature could be as a result of the increasing concentration of starch granules in the continuous phase as well as the boosted association among the granules as alluded to by Gałkowska *et al.* (2014). Similarly, Alam *et al.* (2009) and Lu *et al.* (2020) observed no significant effect on addition of GA on the onset pasting temperature of wheat flour and cassava flour, respectively. Pasting temperature reveals the least temperature needed to cook the flour and also indicates resistance against swelling therefore the addition of GA, in the present study at the concentrations used, resulted in the reduction of energy used.

Peak, Final, Breakdown and Setback viscosities

The results showed that the PV, FV, BV and SB decreased with increasing concentrations of the gum. Maize flour depicted low peak viscosity values as compared to cassava flour **(Table 2)**. These results are consistent with findings by Alam *et al.* (2009) who found that GA significantly reduced the PV of wheat flour. Similarly, Shahzad *et al.* (2021) reported that addition of GA reduced the PV value of gluten-free flour. The reduction in PV values might be attributed to the fact that GA is characterized by low viscosity hence lacking thickening effect. Cassava flour exhibited a higher PV than maize flour and this can be attributed to the lipid content in the latter.

The FV represents the ability of starch to form a viscous paste. A significant decrease in FV was observed in both flours with addition of GA (**Table 2)**. A similar trend was observed by Alam *et al.* (2009) and Shahzad *et al.* (2021) where addition of GA decreased significantly the final viscosity (FV) of wheat flour batter and gluten-free flour respectively though other gums caused an increase in the FV. The decrease in the FV could be ascribed to the starch dilution effect of the flour due to gum substitution. With increasing amounts of GA, maize flour did not exhibit significant difference in the breakdown of viscosity values as compared with cassava flour where the breakdown reduced significantly with increasing amount of gum. The latter finding agrees with Alam *et al*. (2009) and Chhabra *et al.* (2018) who reported that GA greatly reduced the breakdown which the authors attributed to the tightening of the cassava starch granules which made it more heat resistant hence requiring more cooking time. Lu *et al.* (2020) also reported a similar effect with xanthan gum and cassava flour.

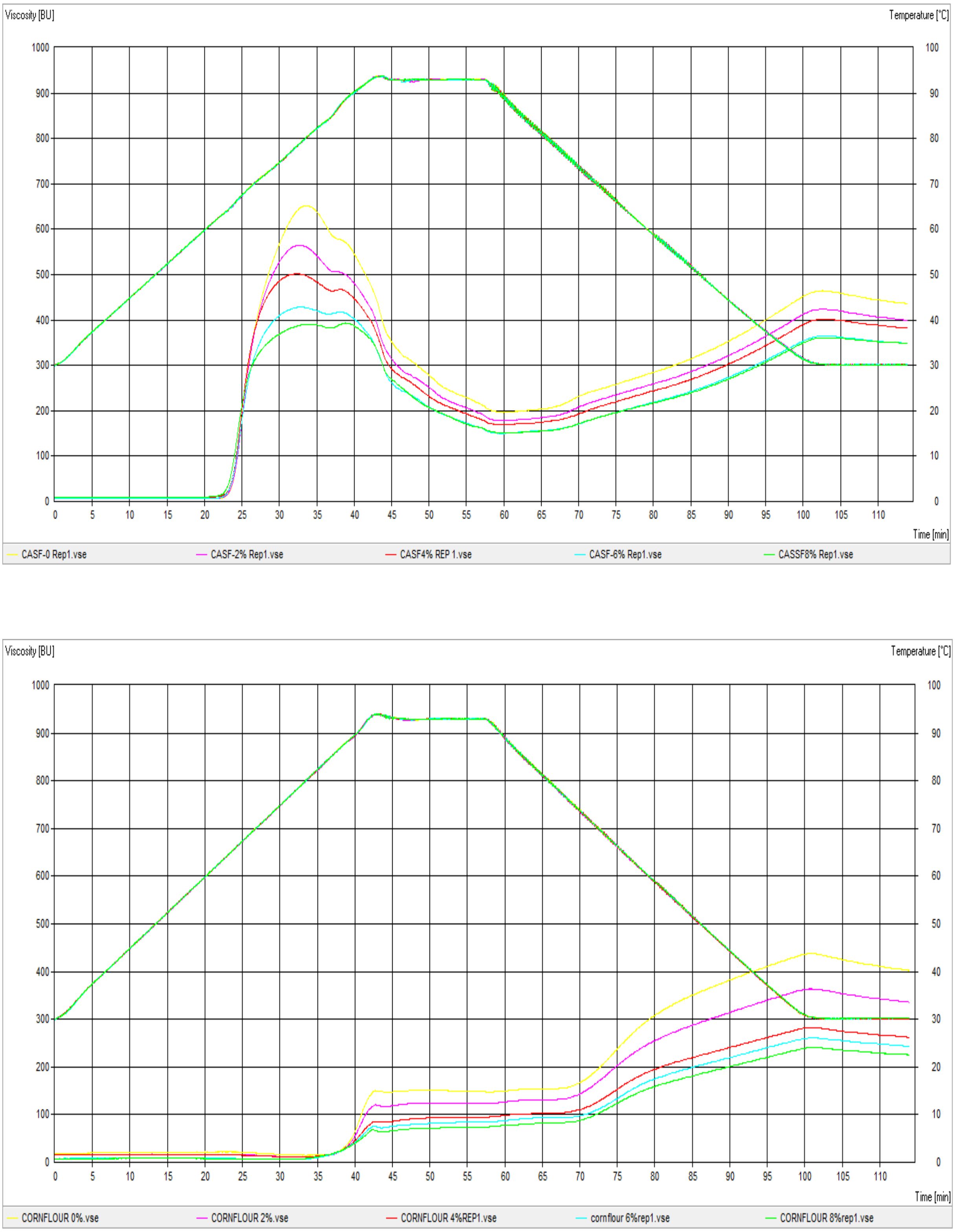

Figure 2: Pasting curves of (a) cassava flour- gum Arabic systems (b) maize flour-gum Arabic system

According to Park *et al.* (2007) low breakdown viscosity of flour can be used in the production of dishes that do not need to stick together though retaining its firmness. Setback viscosity commonly used as an indicator of starch retrogradation that involves the re-association of starch granules to a partially ordered state, significantly decreased with GA addition (**Table 2**). The same observation was reported by Shahzad *et al.* (2021) where GA significantly decreased the setback viscosity of gluten free flour compared to that of the control sample. Furthermore, another study by Sidhu and Bawa (2004) recorded similar findings where wheat flour pasted with GA resulted in lower setback values. The peak, final, set back and breakdown viscosity decreased gradually as the gum concentration increased (0% to 8%) as shown by the pasting correlation curves (**Figure 2**). This could be attributed to higher concentration of GA in the paste matrix that might have resulted in poor paste formation due to poor interaction of starch molecules (Sahni *et al.,* 2020). The tendency of gum molecules to form hydrogen bonds with amylose molecules and covering the surface of starch granules with resultant hindrance in the swelling of starch granules with the consecutive leaching of amylose to thicken the paste resulted in low peak viscosity (Gałkowska *et al.,* 2013; Ma *et al.,* 2019).

Conclusion and Recommendation

Addition of GA to corn and cassava flour significantly modified the pasting and textural properties. These findings highlight a decrease in onset pasting temperature and viscosities of the flour with increasing levels of gum Arabic incorporation. The difference between maize and cassava flour can be attributed to the nature of flour, particle size difference of flour, varietal difference and amylose-lipid complex formation. The setback values which are regarded as a measure of gelling ability or retrogradation tendency reduced hence stability of the paste increased indicating that the gum could be an appropriate candidate for preventing retrogradation and staling in flour-based products. This study suggests that gum Arabic from *A. senegal* var. *kerensis* (Kenyan variety) could be considered in the preparation of various food products from cassava and maize flour to improve the binding ability, stability and prevent retrogradation. We therefore, recommend more research that incorporates this gum as a gluten substitute into gluten free bakery products based on the aforementioned maize and cassava flour to enhance their application.

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