Scientific Research Publishing

Food and Nutrition Sciences, 2024, 15, 298-312
https://www.scirp.org/journal/fns
ISSN Online: 2157-9458
ISSN Print: 2157-944X

Effect of Gum Arabic from *Acacia senegal* var. *kerensis* as an Improver on the Rheological Properties of Wheat Flour Dough

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How to cite this paper: Kiama, R.M., Omwamba, M., Wanjala, G.W. and Mahungu, S.M. (2024) Effect of Gum Arabic from *Acacia senegal* var. *kerensis* as an Improver on the Rheological Properties of Wheat Flour Dough. *Food and Nutrition Sciences*, **15**, 298-312.
https://doi.org/10.4236/fns.2024.154020

Received: February 8, 2024
Accepted: April 26, 2024
Published: April 29, 2024

Abstract

Dough improvers are substances with functional characteristics used in baking industry to enhance dough properties. Currently, the baking industry is faced with increasing demand for natural ingredients owing to increasing consumer awareness, thus contributing to the rising demand for natural hydrocolloids. Gum Arabic from *Acacia senegal* var. *kerensis* is a natural gum exhibiting excellent water binding and emulsification capacity. However, very little is reported on how it affects the rheological properties of wheat dough. The aim of this study was therefore, to determine the rheological properties of wheat dough with partial additions of gum Arabic as an improver. Six treatments were analyzed comprising of: flour-gum blends prepared by adding gum Arabic to wheat flour at different levels (1%, 2% and 3%), plain wheat flour (negative control), commercial bread flour and commercial *chapati* flour (positive controls). The rheological properties were determined using Brabender Farinograph, Brabender Extensograph and Brabender Viscograph. Results showed that addition of gum Arabic significantly ($p < 0.05$) increased dough development time (1.44 - 6.45 minutes), water absorption capacity (59.34% - 59.96%), stability (6.34 - 10.75 minutes), mixing tolerance index (12.00 - 35.80), Farinograph quality number (48.60 - 122.20) and time to breakdown (4.33 - 12.05 minutes). However, there was no significant effect of gum Arabic addition on dough consistency (490 - 505 BU). In extensograph properties, energy was significantly ($p < 0.05$) higher in wheat flour containing 2% gum Arabic (108.44 cm^2), while extensibility was significantly higher in wheat flour containing 3% gum Arabic (153.11 mm). Gum Arabic significantly ($p < 0.05$) decreased all the Viscograph parameters apart from the pasting temperature (69.82˚C - 71.68˚C). The findings of this study show that gum Arabic significantly ($p < 0.05$) enhanced the rheological properties of the dough.

An optimal gum Arabic concentration of 2% in wheat flour dough is recommended for pan bread and 3% for *chapati*. These findings support the need to utilize gum Arabic from *Acacia senegal* var. *kerensis* as a dough improver.

Keywords

Gum Arabic, Improver, Rheology, Hydrocolloids, Wheat Dough

1. Introduction

Dough improvers are substances with functional attributes added to enhance the rheological characteristics of dough and increase the quality attributes of the final product [1]. They impact on dough properties such as water absorption capacity (WAC), dough development time (DDT), dough stability, strength, extensibility and viscosity [2]. Commonly used improvers include oxidizing agents such as potassium bromate, azodicarbonamide, sodium metabisulfite, L-cysteine, potassium iodate and ascorbic acid which act by enhancing the sulfhydryl and disulfide groups in the gluten network thus increasing dough strength [1] [3]. Surfactants such as lecithin, calcium stearoyl lactylate (CSL), diacetyl tartaric esters of mono and diglycerides (DATEM) act by enhancing dough strength [4]. Another group of improvers is enzymes such as α-amylase, bacterial α-amylase and xylanase which hydrolyze starch thus providing fermentable sugars [5]. There is an increasing demand for natural dough modifying additives in the baking industry to improve the quality of wheat flour [6], thus the need to identify natural additives to enhance dough rheology [4].

The application of natural hydrocolloids to modify doughs based on their rheological and physical properties has been rising [7]. Hydrocolloids have good water binding abilities owing to dense hydrophilic groups and different chemical structures, thus the ability to modify the rheology of systems [8]. Hydrocolloids such as guar gum, xanthan gum and locust bean gums have been used in the baking industry to slow staling rate, improve texture, increase water absorption, reduce retrogradation, prevent the loss of quality in frozen dough and improve the structural quality of gluten-free baked products [2] [9] [10]. Studies have reported improved rheological properties such as enhanced water absorption, increased extensibility and improved pasting properties upon addition of gums in wheat bread making [2] [11].

Gum Arabic from *Acacia senegal* var. *kerensis*, is a dried exudate extracted from Acacia senegal stems and branches [12] [13]. It consists of highly branched molecules of hydrophilic sugar residues and hydrophobic amino acids in the arabinogalactan protein (AGP). It has a high molecular weight of approximately 1.19×10^6 [12] with the viscosity of its solution lower than other polysaccharides of similar molecular mass [14]. Gum Arabic from *Acacia senegal* var. *kerensis* application in food is increasing since it has exhibited desirable effects such as enhanced food texture, higher water binding capacity, excellent emulsification and improved shelf life [12] [13].

Gum Arabic has viscoelastic properties which mimic gluten and have been used in making high quality bread using wheat-plantain composite flours [15]. In the report by [15], bread containing up to 40% replaced wheat flour was found to exhibit high quality characteristics. However, there are few reports showing the impact of gum Arabic from *Acacia senegal* var. *kerensis* on the rheological properties of wheat flour-based dough. Thus, the objective of this study was to examine the effect of gum Arabic from *Acacia senegal* var. *kerensis* on the rheological characteristics of the wheat flour dough. We hypothesized that addition of gum Arabic from *Acacia senegal* var. *kerensis* would improve the rheological properties of wheat flour dough. The findings from this study provide empirical data on possible applications of gum Arabic in the baking industry, leading to enhanced gum Arabic utilization.

2. Materials and Methods

2.1. Materials

Wheat flour (Russian type, not treated with any additive) was obtained from Unga Limited-Nairobi. Gum Arabic was obtained from Acacia EPZ Limited, Athi River, Off Nairobi-Namanga Highway. The gum Arabic was prepared by removal of foreign matter and milled into a fine powder using a roller mill (UTL USCH/UZ-Bauermeister GmbH, Hamburg, Germany) with a mesh size of 0.8 mm at the Cereal Chemistry laboratory at the Kenya Industrial Research and Development Institute (KIRDI), Nairobi. The gum Arabic was stored in airtight containers.

2.2. Experimental Design

The study employed a completely randomized design (CRD) in determination of Farinograph and Viscograph properties whereby the treatments were: Plain wheat flour, gum Arabic added at varying levels (1%, 2%, 3%) to wheat flour, commercial bread (pan bread) flour and commercial *chapati* (flat bread) flour which were the positive controls. Commercial bread flour had an improver comprising of a mixture of alpha-amylase enzyme, emulsifiers, an oxidizing agent and a preservative while in commercial *chapati* flour the improver present had enzymes and emulsifiers. Completely randomized design in factorial arrangement was used in determination of extensograph properties. The factors were the different gum Arabic levels/commercial flours and the resting time. The study was carried out in triplicates.

2.3. Rheological Analyses

2.3.1. Farinograph Test

A Brabender Farinograph-AT (Brabender GmbH & Co. KG, Duisburg, Germany) was used to determine parameters such as water absorption (WAC), dough development time (DDT), stability (S), mixing tolerance index (MTI) and Farinograph quality number (FQN) according to AACC 2000 method 54 - 21.02 [16]. A flour sample weighing 300 g on a 14% moisture basis was placed in a farinograph mixing bowl and water (estimated from the farinograph at 500 BU) added to form a dough. As the dough was being mixed, a curve was recorded by the Farinograph. The curve was centered on the 500 Brabender Unit (BU) line ± 20 BU by adding the appropriate amount of water and run until the curve left the 500-BU line. The Farinograph data was recorded at the end of the test.

2.3.2. Uniaxial Extension Test

The uniaxial extension test of the dough was carried out using a Brabender extensograph-E (Brabender GmbH & Co. KG, Duisburg, Germany) according to AACC 2000 method 54 - 10.01 [16]. Dough was made in the Farinograph-AT using 300 g of flour/gum sample, water (estimated from the Farinograph at 500 BU) and 6 g of salt. Dough was shaped into a standard cylindrical shape using the extensograph molder. The test piece of dough was allowed to rest in the extensograph rest cabinet for 45 min at 30˚C. After this period, the dough was stretched after 45, 90 and 135 minutes by the extensograph hook until it ruptured. The stretching force was recorded as a function of time. Measurements of maximum resistance, the extensibility, the energy and the maximum resistance to extensibility ratio (R/E) were recorded.

2.3.3. Pasting Properties

Pasting properties were determined using a Brabender Viscograph-E (Brabender GmbH & Co. KG, Duisburg, Germany) using AACC 2000 method 22 - 12.01 [16] at 85 rpm and 700 cmg torque. About 40 g flour/gum sample adjusted to 14% moisture content was completely dispersed in 420 ml distilled water and added into a Viscograph-E canister. This was followed by heating the slurry from 30˚C to 93˚C at a rate of 1.5˚C/min, held at 93˚C for 15 min followed by cooling to 30˚C at a rate of 1.5˚C/min and finally held at 30˚C for 15 min. Curves of torque (Brabender Units [BU] versus time [min]) were generated for each sample. The curves were used to generate pasting temperature (˚C), peak viscosity (BU), lowest viscosity (BU), breakdown viscosity (BU), setback viscosity and final viscosity.

2.4. Data Analysis

Data was analyzed using the PROC GLM procedure of the Statistical Analysis System (SAS Institute Inc., 2006) software Version 9.4. Before analysis, data was subjected to normality and homogeneity test. Study hypotheses was tested by performing analysis of variance (ANOVA) and the level of significance established at $\rho<0.05$ confidence level. The difference between the means was obtained by Tukey Honest significant difference. The samples were analyzed in triplicates.

3. Results and Discussion

3.1. Dough Development Properties (Farinograph Properties)

Farinograph analysis is carried out to determine the flour attributes during the mixing phase and development of the dough [17]. The effect of gum Arabic addition level to wheat flour dough on Farinograph properties is shown in **Table 1**. The results indicate that the addition of gum Arabic as an improver in wheat dough had a significant ($p < 0.05$) positive influence on all Farinograph properties except for dough consistency that remained largely unchanged. Wheat dough with 3% gum Arabic showed a significantly ($p < 0.05$) higher dough development time, water absorption capacity, dough stability, mixing tolerance index, Farinograph quality number and time to breakdown. Plain wheat flour recorded the lowest values (**Table 1**). The commercial *chapati* flour recorded a significantly ($p < 0.05$) lower dough development time, water absorption capacity, stability, farinograph quality number and time to breakdown except minimum tolerance index. There was no significant difference between commercial bread flour and wheat flour containing 1% gum Arabic in all Farinograph properties apart from time to breakdown.

Water absorption capacity (WAC) varied between 59.34% and 59.96% (**Table 1**). The results indicate a linear relationship with quantity of gum Arabic added to the wheat flour. The increase in gum Arabic resulted in an increase in the WAC. The results obtained are in consistent with previous studies reported by [18] whereby increasing Arabic gum level recorded an increase in water absorption capacity in pan bread flour. Commercial *chapati* flour recorded the lowest water absorption capacity while commercial bread flour was comparable to wheat flour containing 1% gum Arabic. Wheat flour with 3% had the highest water absorption capacity with a notable increase observed with the increase in gum addition. This shows that there was more uptake of water with increase in gum Arabic which can be attributed to the high number of hydroxyl groups in gum Arabic which increased the interactions with water molecules [19].

Dough development time (DDT) varied between 1.44 and 6.45 minutes and was significantly ($p < 0.05$) influenced by the percentage of gum Arabic added to wheat flour (**Table 1**). The results show an increasing trend with corresponding increase in gum Arabic additions. Compared to commercial bread flour and *chapati* flour, the DDT increased approximately 1.5 - 4.5 times to wheat flour with 3% gum Arabic. The DDT are within the acceptable times, very low times may also indicate lower quality protein flours and a weaker gluten network [20]. The increase in dough development time shows that gum Arabic addition to the wheat flour increased the optimum mixing time for the dough. This is attributed to flours with higher protein content since it takes more time for hydration to achieve the desired gluten network [9] [20].

Dough stability (S) was significantly ($p < 0.05$) influenced by the percentage of gum Arabic added to wheat flour (**Table 1**). The dough stability varied between 6.34 and 10.75 minutes indicating and increase in stability upon the incremental addition of gum Arabic to wheat flour. The flour with 1% gum Arabic had a similar stability with the commercial bread and *chapati* flours (**Table 1**). The results are in line with [21], who reported an increase in dough stability upon addition of Acacia gum to wheat flour. Dough stability time indicates tolerance to under or over mixing and is related to the overall quality of protein [22]. Increase in stability upon addition of gum Arabic indicated that there was an increase in the flour strength. Therefore, the increased time the dough maintained the maximum consistency showed that gum Arabic strengthened the gluten network. Flours with longer stability times are generally suited for bread production and often require longer mixing times.

Mixing tolerance index (MTI) in Brabender units was not significantly ($p < 0.05$) influenced by the addition of gum Arabic to the wheat flour (**Table 1**). The MTI values after addition of gum Arabic were above 30 BU but below 50 BU. Commercial bread flour did not differ significantly ($p < 0.05$) with the samples containing gum Arabic but commercial *chapati* flour recorded significantly lower MTIs. The MTI for the flours after addition of gum Arabic were slightly above 30 BU which indicated an acceptable tolerance to mixing. Generally, acceptable MTI values below 50 BU indicates better mechanical properties in dough development [9]. Above 50 BU, there will be less tolerance often indicating difficulties in mechanically handling of the dough. Higher MTI values in wheat flour containing gum Arabic indicated that there was a higher degree of softening and the dough formed were less stiff compared to the control [20].

Farinograph quality number (FQN) varied between 48.60 and 122.20 (**Table 1**). The results indicated a linear relationship with the quantity of gum Arabic added to wheat flour. The increase in gum Arabic resulted in an increase in the FQN. The results obtained are consistent with previous studies reported by [2]. There was no significant ($p < 0.05$) difference in FQN between commercial *chapati* flour, wheat flour containing 1% gum Arabic and commercial bread flour. FQN value is an indication of flour strength with higher values showing higher strength [2]. Dough with added gum Arabic exhibited significantly ($p < 0.05$) higher FQN values which indicates an increase in the strength of the flour.

Time to breakdown varied between 4.33 and 12.05 minutes (**Table 1**). The results indicate a linear relationship with quantity of gum Arabic added to the wheat flour. The increase in gum Arabic resulted in an increase in the TBD. The results obtained are consistent with previous studies reported by [21]. Time to break down in commercial *chapati* flour was similar to wheat flour containing 1% gum Arabic while in commercial bread flour it was similar to wheat flour containing 2% gum Arabic. Time to breakdown increased with addition of gum Arabic and upon the use of commercial *chapati* and bread flour. This shows that there was an increase in the time the gluten structure broke down after reaching its full development.

The addition of gum Arabic exhibited qualities associated with high quality protein flour such as higher dough development time, dough stability and Farinograph quality number. It enhanced the Farinograph properties through

Table 1. Effect of gum Arabic addition level in wheat dough on Farinograph properties.

Treatment	Dough Development Time (DDT) (min)	Consistency (BU)	Water Absorption Capacity (WAC) (%)	Stability (S) (min)	Mixing Tolerance Index (M.T.I)	Farinograph Quality Number (F.Q.N)	Time to Breakdown (TBD) (min)
WFCF	4.22 ± 0.05^{c}	498.20 ± 1.50^{a}	59.34 ± 0.07^{c}	8.25 ± 0.08^{c}	24.80 ± 1.83^{b}	89.60 ± 1.86^{c}	8.78 ± 0.17^{c}
WFGA0	1.44 ± 0.01^{d}	496.00 ± 5.77^{a}	59.44 ± 0.04^{bc}	6.34 ± 0.10^{d}	12.00 ± 0.32^{c}	48.60 ± 2.71^{d}	4.33 ± 0.05^{d}
WFGA1	1.34 ± 0.01^{d}	505.80 ± 4.50^{a}	59.50 ± 0.10^{abc}	8.17 ± 0.06^{c}	35.80 ± 1.28^{a}	89.40 ± 1.12^{c}	8.81 ± 0.16^{c}
WFGA2	5.84 ± 0.14^{b}	490.00 ± 1.90^{a}	59.90 ± 0.10^{ab}	9.62 ± 0.10^{b}	34.00 ± 0.55^{a}	108.00 ± 1.87^{b}	10.36 ± 0.04^{b}
WFGA3	6.45 ± 0.03^{a}	495.00 ± 4.18^{a}	59.96 ± 0.04^{a}	10.75 ± 0.14^{a}	34.20 ± 0.86^{a}	122.20 ± 1.20^{a}	12.05 ± 0.13^{a}
WFVB	1.46 ± 0.03^{d}	499.00 ± 2.85^{a}	59.58 ± 0.20^{abc}	8.16 ± 0.06^{c}	32.20 ± 1.46^{a}	86.40 ± 2.40^{c}	9.94 ± 0.13^{b}

Key: DDT-dough development time, WAC-water absorption capacity, S-stability, M.T.I-minimum tolerance index, F.Q.N-farinograph quality number, TBD-Time to breakdown, min-minutes, BU-Brabender Units. WFCF-commercial *chapati* flour, WFGA0-plain wheat flour, WFGA1-wheat flour with 1% gum Arabic, WFGA2-wheat flour with 2% gum Arabic, WFGA3-wheat flour with 3% gum Arabic, WFVB-commercial bread flour. Means sharing the same letters within a column are not significantly different (Tukey Honest significant difference at $p < 0.05$).

enhancement and reinforcement of a strong gluten network [9].

3.2. Extensograph Properties

An extensograph is used to measure dough resistance to stretching and the distance the dough stretches before it ruptures. It examines the behavior of dough at further stages of proofing and baking [19]. The effect of gum Arabic addition level in wheat dough on extensograph properties are shown in **Table 2**. The commercial bread flour recorded a significantly ($p < 0.05$) higher energy, resistance to extension, ratio number but the lowest extensibility. There was no significant ($p < 0.05$) difference in energy between the commercial bread flour and wheat flour with 2% gum Arabic. Wheat flour with 2% gum Arabic recorded the second highest resistance to extension while there was no significant ($p < 0.05$) difference in wheat flour with 1%, 3% gum Arabic and commercial *chapati* flour. Wheat flour with 3% gum Arabic recorded a significantly higher extensibility with wheat flour with 0%, 1%, 2% of gum Arabic having no significant ($p < 0.05$) difference.

The energy was significantly ($p < 0.05$) influenced by the percentage of gum Arabic added to the wheat flour (**Table 2**). Energy varied between 94.22 and 108.44 cm^2 indicating an increase in energy upon incremental addition of gum Arabic to 2% with a decrease at 3% gum Arabic addition. Wheat flour with 2% gum Arabic had the highest energy. The results are consistent with [18] whereby addition of Arabic gum to wheat flour resulted in increase in energy in lower levels of Arabic gum but a reduction in energy at higher levels.

Resistance to extension varied between 362.89 and 596.56 Brabender Units (**Table 2**). The results indicate a non-linear relationship whereby there was a significant increase in resistance to extension up to 2% gum Arabic addition

Table 2. Effect of gum Arabic addition level in wheat dough on extensograph properties.

Treatment	Energy (cm^2)	Resistance to Extension (BU)	Extensibility (mm)	Ratio Number (Ratio No)
WFCF	100.22 ± 2.45^{b}	364.89 ± 10.86^{c}	152.67 ± 0.53^{b}	2.37 ± 0.08^{c}
WFGA0	94.22 ± 1.34^{d}	362.89 ± 7.52^{c}	146.00 ± 1.91^{c}	2.43 ± 0.09^{bc}
WFGA1	96.11 ± 1.48^{cd}	383.56 ± 7.27^{c}	145.11 ± 1.82^{c}	2.62 ± 0.08^{b}
WFGA2	108.44 ± 2.64^{a}	405.33 ± 9.34^{b}	146.67 ± 1.39^{c}	2.64 ± 0.05^{b}
WFGA3	99.00 ± 1.03^{bc}	380.11 ± 6.94^{c}	153.11 ± 1.39^{a}	2.66 ± 0.09^{b}
WFVB	105.33 ± 2.62^{a}	596.56 ± 33.24^{a}	123.11 ± 3.60^{d}	4.98 ± 0.42^{a}

WFCF-commercial *chapati* flour, WFGA0-plain wheat flour, WFGA1-wheat flour with 1% gum Arabic, WFGA2-wheat flour with 2% gum Arabic, WFGA3-wheat flour with 3% gum Arabic, WFVB-commercial bread flour, Ratio No-ratio number, BU-Brabender Units, mm-millimeters. Means sharing the same letters within a column are not significantly different (Tukey Honest significant difference at $p < 0.05$).

with a significant decrease at 3% gum Arabic addition. Commercial bread flour recorded the highest resistance to extension. In previous results, [21] reported impaired resistance to extension of the dough upon addition of 3% and 6% Acacia gum to wheat flour. There was no significant difference between commercial *chapati* flour, wheat flour containing 1% and 3% gum Arabic in resistance to extension.

Dough exhibiting stronger resistance to extension and energy at the moment of sample rupture has better bread making quality [18]. The commercial bread flour recorded significantly ($p < 0.05$) higher resistance to extension due to the presence of different types of improvers including amylases, emulsifiers and ascorbic acid which positively worked on the dough synergistically. The energy and resistance to extension recorded an increase upon addition of 2% gum Arabic, which indicates maximum strength and dough's ability to hold gas (**Table 2**). Wheat flour with 2% gum Arabic is most preferred in pan bread making since it had significantly higher energy and resistance to extension and was most comparable with the commercial bread flour. Addition of gum Arabic in higher levels of 3% to wheat flour resulted in lower energy and resistance to extension. This shows that there was presence of high levels of hydrogen bonds and increased moisture content in flours that had higher levels of gum Arabic. These attributes led to a softer texture that is attributed to the loosening of dough structure leading to weaker strain resistance [17].

The extensibility varied between 123.11 and 153.11 mm (**Table 2**). Wheat flour with 3% gum Arabic had a significantly ($p < 0.05$) higher extensibility with levels 0%, 1%, 2% showing no significant difference among the levels. These results are consistent with [9], who recorded an increase in dough extensibility upon addition of Acacia gum to wheat flour. Wheat flour with gum Arabic at 3% yielded the best extensibility which shows that gum Arabic was favorable for formation of more extensible dough. A dough with high extensibility is more preferred for making of flat breads such as *chapati*. This therefore indicates that, since wheat flour with 3% gum Arabic was almost comparable to the commercial *chapati* flour, it is ideal for flat bread production.

The ratio number varied between 2.37 and 4.98 (**Table 2**). Commercial bread flour had significantly ($p < 0.05$) higher ratio number while commercial *chapati* flour had significantly ($p < 0.05$) lower ratio number. Wheat flour with 1%, 2%, and 3% gum Arabic had similar ratio number. A good flour for pan bread making should have a favorable ratio of resistance to extension to extensibility and should fall between 2 to 3 [18]. The results show that the ratio number of all the flours with gum Arabic fell in this category with a notable increase upon addition of gum Arabic. This shows that the flours had good bread making properties due a favorable ratio of high mechanical strength and high extensibility.

The effect of resting time in wheat dough containing gum Arabic on extensograph properties is shown in **Figure 1**. Significant ($p < 0.05$) difference in the different measuring times was recorded in all extensograph properties apart from resistance to extension which did not show any significant ($p < 0.05$) difference between the 90th and 135$_{th}$ minute resting time. The extensograph analysis after the 90th minute recorded significantly ($p < 0.05$) higher energy, ratio number and resistance to extension (**Figure 1**).

Extensibility was significantly ($p < 0.05$) higher after the 45th minute followed by the 90th minute. It shows that the gluten network was already formed by the

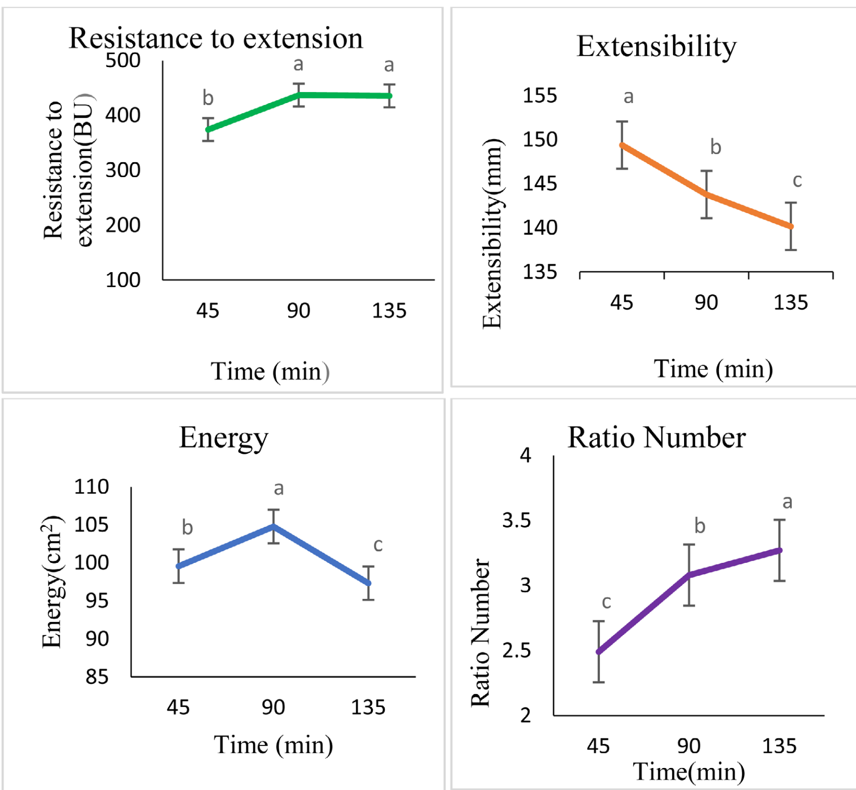

Figure 1. Effect of resting time in wheat dough containing gum Arabic on extensograph properties.

90th minute and there was minimal resistance to the formation of the gluten network. Extension of proofing time to 135th minutes caused a significant decrease in the resistance to extension, energy and extensibility which could have been attributed to disintegrating of the gluten network with over proofing. This indicates that 90 minutes would be sufficient proofing time in bread production.

Effect of gum Arabic addition and resting time on extensograph properties of wheat dough are shown in **Table 3**. The energy varied between 89.00 and 117.67 cm^2 (**Table 3**). Wheat flour with 2% gum Arabic at the 90th minute recorded the significantly ($p < 0.05$) higher energy while plain wheat flour at 135th minute was significantly lower. The resistance to extension varied between 321.67 and 671.33 Brabender Units. The commercial bread flour at 135th minute recorded a significantly higher resistance to extension, while wheat flour with 2% gum Arabic at

Table 3. Effect of gum Arabic addition and resting time on extensograph properties of wheat dough.

Treatment	Time (min)	Energy (cm^2)	Resistance to Extension (BU)	Extensibility (mm)	Ratio No
WFCF	45	90.67 ± 0.33^{ij}	321.67 ± 1.45^{g}	153.67 ± 0.33^{ab}	2.07 ± 0.03^{g}
	90	104.67 ± 1.33^{bcde}	385.33 ± 1.33^{def}	152.33 ± 1.20^{ab}	2.50 ± 0.00^{defg}
	135	105.33 ± 1.20^{bcd}	387.67 ± 2.85^{cdef}	152.00 ± 1.00^{abc}	2.53 ± 0.03^{defg}
WFGA0	45	96.67 ± 0.33^{efghij}	357.33 ± 5.21^{efg}	152.00 ± 1.53^{abc}	2.33 ± 0.07^{defg}
	90	97.00 ± 0.00^{efghij}	343.33 ± 6.77^{efg}	146.33 ± 1.33^{bcde}	2.20 ± 0.10^{fg}
	135	89.00 ± 1.00^{j}	388.00 ± 9.17^{cdef}	139.67 ± 1.20^{ef}	2.77 ± 0.03^{dc}
WFGA1	45	99.67 ± 0.88^{degh}	362.00 ± 1.15^{efg}	152.00 ± 1.00^{abc}	2.30 ± 0.00^{efg}
	90	96.00 ± 2.52^{fghij}	408.67 ± 8.67^{cd}	143.00 ± 1.00^{ef}	2.80 ± 0.00^{de}
	135	92.67 ± 2.60^{hij}	380.00 ± 2.08^{def}	140.33 ± 0.67^{ef}	2.77 ± 0.03^{de}
WFGA2	45	103.33 ± 1.33^{bcdef}	375.00 ± 4.04^{def}	151.00 ± 1.00^{abcd}	2.53 ± 0.07^{defg}
	90	117.67 ± 3.84^{a}	432.33 ± 13.17^{bc}	144.33 ± 1.20^{de}	2.73 ± 0.12^{de}
	135	104.33 ± 1.76^{bcde}	408.67 ± 5.17^{cd}	144.67 ± 2.60^{cde}	2.67 ± 0.03^{def}
WFGA3	45	97.33 ± 1.20^{defgh}	361.33 ± 3.71^{efg}	151.33 ± 1.33^{abcd}	2.37 ± 0.03^{defg}
	90	102.00 ± 1.53^{cdef}	402.00 ± 1.53^{cde}	155.67 ± 2.73^{a}	2.77 ± 0.09^{de}
	135	97.67 ± 1.45^{defghi}	377.00 ± 11.85^{def}	152.33 ± 2.96^{ab}	2.83 ± 0.18^{d}
WFVB	45	109.67 ± 0.88^{abc}	468.00 ± 12.06^{b}	136.33 ± 1.86^{f}	3.37 ± 0.12^{c}
	90	111.33 ± 0.88^{ab}	650.33 ± 13.69^{a}	121.00 ± 1.00^{g}	5.50 ± 0.21^{b}
	135	95.00 ± 0.00^{ghij}	671.33 ± 20.54^{a}	112.00 ± 0.00^{h}	6.07 ± 0.20^{a}

WFCF-commercial *chapati* flour, WFGA0-plain wheat flour, WFGA1-wheat flour with 1% gum Arabic, WFGA2-wheat flour with 2% gum Arabic, wheat flour with 3% gum Arabic, WFVB-commercial bread flour, Ratio No-ratio number, BU-Brabender Units, mm-millimeters, min-minutes. Means sharing the same letters within a column are not significantly different (Tukey Honest significant difference at $p < 0.05$).

135th minute recorded a significantly ($p < 0.05$) higher resistance to extension in the different levels of gum Arabic addition. The ratio number varied between 2.07 and 6.07. It was significantly higher in the commercial bread flour at 135th minute but lowest in commercial *chapati* flour at 45th minute. Extensibility was significantly ($p < 0.05$) higher in wheat flour with gum Arabic at 3% at 90th minute but lowest in commercial bread flour at 135th minute. It varied between 112.00 and 155.67 mm.

Good baking properties are exhibited in flours with greater resistance to extension and extensibility which also results to greater energy [17]. Effect of wheat flour with 2% gum Arabic and 90th minute resting time resulted to significantly ($p < 0.05$) higher energy. Commercial bread flour recorded a significantly ($p < 0.05$) higher resistance to extension across the three different measuring times followed by wheat flour with 2% gum Arabic at the 90th minute. Wheat flour with 3% gum Arabic at 90th minute recorded significantly ($p < 0.05$) higher extensibility which indicates enhanced viscous flow of dough. Most of the parameters were significantly ($p < 0.05$) higher at the 90th minute which shows that the maximum changes in the biochemical activity of the dough influenced by either the inherent flour properties or presence of improver had already occurred.

3.3. Pasting Properties

Effect of gum Arabic addition level in wheat dough on Viscograph properties are shown in **Table 4**. Plain wheat flour recorded significantly higher Viscograph properties while wheat flour containing 3% gum Arabic recorded significantly lower Viscograph properties apart from the pasting temperature. Compared to plain wheat flour, all the properties apart from pasting temperature decreased approximately 2 times to wheat flour with 3% gum Arabic. Pasting temperature was significantly ($p < 0.05$) lower in commercial bread flour. A general decrease was recorded in peak viscosity, minimum viscosity, final viscosity, breakdown and setback as the level of gum Arabic increased. The results are in line with [10] who reported a significant decrease in all Viscograph properties apart from the pasting temperature with increasing substitution levels of gum Arabic in corn and cassava starches.

The pasting temperature varied between 69.50˚C and 71.68˚C (**Table 4**). It was significantly higher in plain wheat flour but significantly lower in commercial bread flour. There was no significant difference between commercial *chapati* flour and wheat flour containing 1% gum Arabic. Pasting occurs when starch granules are continually heated in sufficient amount of water leading to granule swelling and leaching of the starch molecules [23]. The leaching of amylose as a result of granule swelling leads to an increase in viscosity while the rupture of the granules upon further heating leads to a decrease of the same. Pasting temperature is the temperature at the onset of gelatinization [21]. The results show that plain wheat flour did not differ significantly from wheat flour with 3% gum Arabic (**Table 4**). This is an indication that addition of gum Arabic did not affect the onset of gelatinization showing that minimum energy would be required for cooking the flours. Commercial wheat flour had a significant ($p < 0.05$) decrease in the pasting temperature. This suggests that the amylases present in the commercial flour broke down the starch into its different saccharides and monosaccharides which sped up the gelatinization process, consequently lowering the gelatinization temperature.

Peak viscosity was significantly ($p < 0.05$) influenced by the percentage of gum Arabic added to wheat flour (**Table 4**). It varied from 45.20 and 103.00 BU indicating a decrease in peak viscosity upon the addition of gum Arabic to wheat flour and usage of commercial bread and *chapati* flour. Peak viscosity is the maximum viscosity developed immediately after heating the sample which is indicative of the swelling index or starch solubility [15]. Significant ($p < 0.05$) decrease in the peak viscosity upon addition of gum Arabic suggests that gum Arabic promoted granule association thus, restricted maximum swelling of the starch granules. This affected the leaching out of amylose and starch-gel formation leading to a significant reduction in peak viscosity [10]. Hydrocolloids are able to form stable polymeric network which entraps starch molecules thus delaying the release of amylose molecules which are attributed to the thickening and increase in viscosity [23].

Minimum viscosity was significantly ($p < 0.05$) influenced by gum Arabic addition to wheat flour. It varied between 25.80 and 60.40 BU (**Table 4**) indicating a decrease in minimum viscosity upon addition of gum Arabic and using commercial bread and chapati flour.

Final viscosity varied between 99.00 and 215.20 BU (**Table 4**) and was significantly ($p < 0.05$) influenced by the addition of gum Arabic which shows a constant decreasing trend upon incremental addition of gum Arabic. Final viscosity measures the ability of gelatinized starch to form a paste after cooling. The significant ($p < 0.05$) decrease in final viscosity on addition of gum Arabic shows that it retarded the reaggregation of the leached fractions of starch thus inhibiting

Table 4. Effect of gum Arabic addition level in wheat dough on Viscograph properties.

Treatment	Pasting Temperature (˚C)	Peak Viscosity (BU)	Minimum Viscosity (BU)	Final Viscosity (BU)	Breakdown Viscosity (BU)	Setback Viscosity (BU)
WFCF	69.74 ± 0.58^{bc}	84.00 ± 1.26^{c}	48.80 ± 0.58^{c}	175.00 ± 3.07^{c}	35.20 ± 0.92^{b}	126.20 ± 2.50^{b}
WFGA0	71.68 ± 0.23^{a}	103.00 ± 2.28^{a}	60.40 ± 1.50^{a}	215.20 ± 6.34^{a}	42.60 ± 1.03^{a}	154.80 ± 4.85^{a}
WFGA1	69.82 ± 0.16^{bc}	94.40 ± 1.47^{b}	54.60 ± 0.68^{b}	192.80 ± 1.93^{b}	39.80 ± 1.24^{a}	138.20 ± 1.36^{b}
WFGA2	70.58 ± 0.45^{abc}	67.80 ± 0.86^{d}	38.00 ± 1.05^{d}	138.40 ± 2.54^{d}	29.80 ± 0.49^{c}	100.40 ± 1.69^{c}
WFGA3	71.46 ± 0.56^{ab}	45.20 ± 1.83^{e}	25.80 ± 1.07^{e}	99.00 ± 2.72^{e}	19.40 ± 0.87^{d}	73.20 ± 1.91^{d}
WFVB	69.50 ± 0.49^{c}	74.20 ± 1.71^{d}	40.20 ± 1.11^{d}	149.80 ± 3.48^{d}	34.00 ± 1.30^{bc}	109.60 ± 2.42^{c}

WFCF-commercial *chapati* flour, WFGA0-Plain wheat flour, WFGA1-wheat flour with 1% gum Arabic, WFGA2-wheat flour with 2% gum Arabic, WFGA3-wheat flour with 3% gum Arabic, WFVB-commercial bread flour, BU-Brabender Units. Means sharing the same letters within a column are not significantly different (Tukey Honest significant difference at $p < 0.05$).

an increase in viscosity during cooling [14].

Breakdown viscosity was significantly ($p < 0.05$) influenced by gum Arabic and varied between 19.40 and 42.60 BU (**Table 4**). There was a significant ($p < 0.05$) decrease with incremental addition of gum Arabic. Breakdown viscosity did not differ significantly in commercial *chapati* flour and commercial bread flour. Breakdown is an indicator of granules stability to shear and heat during continuous cooking. In comparison with plain wheat flour, breakdown viscosity was significantly ($p < 0.05$) lower in wheat flour with gum Arabic at 2% and 3%, commercial *chapati* flour and commercial bread flour. This shows that addition of gum Arabic and the presence of commercial improvers contributed to increased starch stability during cooking and the flours were able to withstand the heating and shearing stress during cooking compared to the plain wheat flour [21].

Setback viscosity varied between 73.20 and 154.80 BU (**Table 4**) and was significantly ($p < 0.05$) influenced by addition of gum Arabic. The results show a decreasing trend with increasing addition of gum Arabic. Commercial bread and *chapati* flour also recorded significantly lower setback compared to plain wheat flour. Setback Viscosity indicates the tendency of the dough to undergo retrogradation causing an increase in viscosity [14]. There was a significant ($p < 0.05$) reduction in setback viscosity upon addition of gum Arabic to wheat flour implying a reduction in retrogradation of starch [8] which enhances the storage abilities of the end products [24].

4. Conclusion and Recommendations

The study has provided evidence that addition of gum Arabic from *Acacia senegal* var. *kerensis* positively improved the rheological properties of wheat flour dough. Gum Arabic enhanced dough development time, water absorption capacity, dough stability and Farinograph quality number. The extensograph properties were improved including increased energy, better resistance to extension, ratio number and extensibility. The pasting properties of wheat were modified resulting in reduction of Viscograph parameters except pasting temperature. Gum Arabic significantly improved the properties of wheat dough development stage and also a possible modifier of retrogradation. According to this study, an optimal gum Arabic concentration of 2% in wheat flour dough and 90 minutes proofing time is recommended for pan bread making due to the desirable strength and ability to hold gases. Gum Arabic concentration of 3% in wheat flour dough which had the highest extensibility is recommended for making flat breads such as *chapati*. These findings indicate a positive role of gum Arabic as a dough improver and we recommend further studies for optimization of gum Arabic in baking operations for different baked products.

Acknowledgements

This study was funded through a research grant from Regional Forum for Capacity Building in Agriculture (RUFORUM) through TAGDev, Egerton University, Kenya. The authors extend their appreciation to the Kenya Industrial Research and Development Institute (KIRDI), Nairobi, Kenya for availing the facility and expertise that made the analyses possible.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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