Investigation of the Potentials of the Binding Properties of Mango, Cashew and Blended Gums

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Abstract. This research is aimed at production and investigation of the potentials of blending mango gum with cashew gum on its binding properties as a substitute for gum Arabic. The high demand for adhesives has led to the search for other alternatives to Arabic and cashew gum due to their high cost and non-availability. Thus, the need to investigate the potentials of mango gum as well as the possibility of replacing mango gum with cashew gum to be employed as an adhesive. The raw gum was extracted from the mango tree, dried, sorted, underwent size reduction of the gum exudates, sieved into different mesh sizes, dissolved in distilled water and centrifuged to remove impurities and other polysaccharides. The binding properties of the extracted mango gum was monitored in terms of physicochemical properties such as viscosity, pH and specific gravity of the gum using capillary viscometer, pH meter and density bottle respectively. The variation of the agitation speed between 250, 500 and 750 rpm, particle size of the raw MG between 75 μm, 212 μm and 300 μm and the replacement of MG with CG from 0-50% at interval of 10% respectively. The effect of agitation speed, particle size of the raw MG and the replacement of MG with CG were investigated in terms of the viscosity, pH and specific gravity of the gum and found that the best quality gum was obtained at particle size of 75 μm, pH of 4.7, agitation speed of 500 rpm and specific gravity of 1.06 respectively. Results indicated that the use of additives such as glycerine, starch and zinc oxide enhanced the binding properties of the gum and MG as well as gums blended with CG were found to fall within the limits to be considered to possess good binding properties. An increase in MG replacement with CG up to 50 %, resulted in a decrease in viscosity and specific gravity of the blended gum by 21.32 % and 3.77 % respectively while pH experienced an increase from 4.4-5.7 i.e. more alkaline in nature.

Keywords: Mango gum; Cashew gum; Gum blend; Viscosity; Specific gravity; pH; Agitation speed; Particle size.

INTRODUCTION

Cashew gums are a class of biopolymers obtained from the seed or tree cashew bark (Anacadium Ocidentale) and can be employed industrially as a binder due to its similarity in terms of physico-chemical and rheological properties compared to Arabic gum with applications ranging from thickeners, emulsifiers, binders and stabilizers in the food, paint, pharmaceutical industries respectively [1]. They are hard, yellowish-brown exudates, complex polysaccharide, comprising of high molecular weight hydrocarbons [2, 3]. The cultivation of cashew crops on a large scale is fast becoming a profitable and sustainable activity due to the utilization of cashew gum (resin) which possesses similar properties with Arabic gum. The cashew gum (CG) can be extracted unconventionally from the epithelia cells having canals which secretes via internal cavities which are generally nontoxic in nature [2].

Gums are byproducts of normal plant metabolism which protects against pathological conditions afflicting the plant as well as infection of the plant by microorganisms. These gums are amorphous and hydrophilic in nature and can generally be categorized into natural, modified and synthetic gums [4]. CG falls into the class of natural gum amongst acacia, locust beans which are obtained via exudates from stem barks, branches and roots of plants which are grown in many tropical and subtropical regions including Nigeria. These natural gums are basically either neural or acidic in nature and are predominantly polysaccharide. This is because CG is a raw material of plant origin and possesses relatively nontoxic, biocompatible, readily accessible, economical and cost effective even in industrial scale [5, 6]. One of the shortcomings of natural gum over synthetic gum is the susceptibility of the gum to microbial attack [7, 8]. The gum's chemical composition comprises of 61 % galatose, 14% arabinose, 7 % rhamnose, 8% glucose, 5 % glucuronic acid and <2% other sugar residue [9, 10, 11]. The variation of the acid number of the CG could be affected by its source and trees' age [2, 12]. The extracted gum which is sticky tends to darken and thicken as the exudates is exposed to air, thus finding applications as a vanish for surface protection against acids, alkalis, alcohols and heat less than 70 °C. They are also referred to as plant or microbial polysaccharides and its derivatives which are capable of producing dispersions either in a cold or hot water producing a viscous mixture or solutions [2]. The performance and application of the raw gum is limited to its low viscosity, thermal stability, flammability and functional groups susceptible to enzyme corrosion. Intensive researches on CG indicates that the gum is cost effective, sustainable, non-toxic and biodegradable as well as possesses physico-chemical properties similar to Arabic gum and can be employed as a substitute of liquid glue for paper; as an agglutinant for capsule and pills in the pharmaceutical and cosmetic industries; stabilizers for juice in the food industries [5, 7, 13, 14].

Mango gum (MG) can be extracted from the trunk of mango trees alongside with its fruits. MG is reddish brown gum from the trunk and can be employed as a substitute for gum Arabic. The resinous gum from the trunk can be applied to cracked skin of the feet and on infections like scabies, ringworm, fungi, syphilis and induced sweating. They contain mangiferon, resinol and mangiferol [15]. The physicochemical properties of gum are requisite in determining their uses, economical value and the quality/properties of the produced gum which are dependent on its viscosity, colour and solubility, edaphic factor and climatic condition. The gum with significantly high viscosity (thickness) is an indicator for important purposes. The colour and viscosity is significantly influenced by edaphic factors and climatic conditions [16]. Most gums are hydroscopic in nature, thus, absorb moisture from the environment and softens. The solubility of the gum can be influenced by the age of the tree and the time that the gum was extracted from the tree while the tenacity of the gum is as important as the viscosity as its value is related to the adhesive properties of the gum [17].

Owing to high cost of Arabic gum, researchers have sort for other alternative gum from cashew tree [18] and CG seems to be a convenient gum replacement due to its structural, thermal behavior and viscosity characteristics similarity [19, 20, 21]. Another option is the modification of the gum by blending to improve its properties [1]. The aim of this study is to investigate the potential of replacing CG with MG on the binding properties of produced gum. This research also tried to investigate the effect of particle size, rotation speed and the replacement of CG with MG on the binding properties of the produced gum (in terms of density, pH and viscosity). The optimal conditions for the production of gum binding properties similar to standards/ Arabic gum will be determined.

MATERIALS AND METHODS

Cashew and mango gums were obtained from Niger state as natural exudates by making a scar using an axe about 4 cm deep on the cashew and mango tree trunk and about 1 m distance at the breast height (DBH) above soil level. Glycerine, Starch, Zinc oxide were obtained from the chemical store of ATBU Bauchi. Distilled water was freshly prepared at ATBU Chemical Engineering Laboratory.

Preparation of the exudates. The dried raw cashew and mango tree exudates were purified as a sodium salt using the method previously described [18, 22]. One kilogram (1 kg) of both cashew and mango tree exudates gum sample were collected, sorted out to remove impurities and later dried at 30 °C to reduce the moisture content. The dried samples were ground and passed through 2.5 mm size mesh sieve. The crude CG and MG were then isolated, in order to separate the polysaccharides, present in the raw gums were achieved by stirring the gum samples independently in 250 ml distilled water for 6-8 hours at room temperature. Both solution pH were adjusted to approximately 7.0 by adding diluted NaOH. The samples were then centrifuged to remove the impurities and were concentrated by heating to a temperature of 100 °C. The residues were then washed with water, then ground and separated using sieves of 75, 212 and 300 microns and kept in labeled plastic containers for analysis. Both gums were then modified by the use of additives such as Zinc Oxide, Glycerine, and Starch and the properties of gum were were measured in terms of gum viscosity, pH, and specific gravity respectively. The viscosities, pH and specific gravities of the gums were measured using capillary viscometer (Shott Gerate, Type 501 20/1, Country), pH meter (Sunnih, Model HI9813-5, Country) and 25 cm^3 density bottle at 25 °C respectively. Agitation speed and particle sizes of MG replacement with CG were varied to investigate their effect on blending properties and the optimum condition that gave the best modified gum was noted [24]. Figures 1 (a) and 1 (b) illustrate the raw MG and CG that were extracted from the cashew and mango tree trunks while Figures 1 (c) and 1 (d) indicate the refined CG and MG that were sorted, washed, dried and ground respectively.

Figure 1(a) – Mango gum

Figure 1(b) – Cashew Gum

Figure 1(c) – Dried Mango Gum

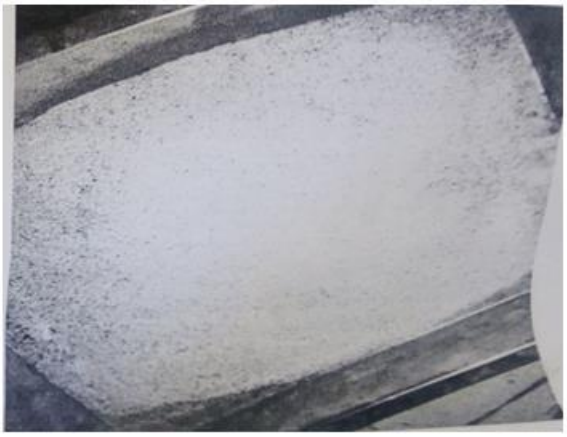

Figure 1(d) – Dried Cashew Gum

RESULTS AND DISCUSSION

Table 1 indicates the physicochemical properties of raw cashew gum and the result showed that the pH and viscosity of the raw CG exudates were 4.7 and 4.89 Ns/m^2 while raw MG exudates were 4.4 and 5.91 Ns/m^2 respectively. The pH values of the raw CG and MG fell within the natural pH range of Arabic gum [23].

Table 2 indicates the effect of agitation speed and particle size on the specific gravity, pH and viscosity of CG, whereas Figures 2–4 illustrate the variation of agitation speed on the viscosity, specific gravity and pH of CG at various particle sizes respectively.

Table 1 – Physicochemical Properties of Raw CG and MG

No	Properties	Raw Cashew gum	Raw Mango gum
1	pH	4.7	4.4
2	Density	1.89	2.10
3	Viscosity Ns/m^2	4.89	5.91
4	Refractive index	1.41	1.35
5	Specific gravity	1.04	1.06
6	Solubility g/ml	1	0.09

Table 2 – Effect of agitation speed and particle size on the specific gravity, pH and viscosity of CG

Agitation speed rpm	250			500			750		
sieve size micron	specific gravity	pH	viscosity Ns/m^2	specific gravity	pH	viscosity Ns/m^2	specific gravity	pH	viscosity Ns/m^2
75	1.02	4.9	4.40	1.06	4.9	5.13	1.05	4.9	5.00
212	1.03	4.7	4.46	1.04	4.7	4.89	1.01	4.8	3.88
300	1.01	4.9	4.11	1.08	4.9	5.20	1.01	4.9	3.90

An increase in the agitation speed (rpm) at constant particle size of 75 μm, from 250–500 rpm (twice the speed) resulted in an increase in the specific gravity from 1.02–1.06 while the viscosity also experienced an increase in its viscosity from 4.40–5.13 Ns/m^2 (16.59 %), whereas when the agitation speed was tripled i.e. increased to 750 rpm, the viscosity and the specific gravity increased from 4.40–5.0 Ns/m^2 (13.64 %) and 1.02–1.05 (2.94 %). At constant particle size of 212 μm, while the agitation speed (rpm) was increased from 250–500 rpm (twice the speed), the specific gravity increased from 1.03–1.04 while the viscosity also experienced an increase in its viscosity from 4.46– 4.89 Ns/m^2 (9.64 %), whereas when the agitation speed was tripled i.e. to 750 rpm, the viscosity and the specific gravity experienced a reduction from 1.03–1.01 (1.94 %) and 4.46–3.88 Ns/m^2 (13 %). The particle size of 300 μm as the agitation speed was doubled, the specific gravity and viscosity increased significantly from 4.11–5.20 Ns/m^2 (26.52 %) and 1.01–1.08 (6.93 %) respectively whereas, when the agitation speed was tripled, the viscosity diminished from 4.11–3.90 Ns/m^2 (5.11 %). The decrease in the viscosity of the gum could be attributed to the friction between the particles of the CG leading to an increase in temperature and then results in a decrease in the gum' viscosity which was evident for particle sizes bigger than 75 μm. According to [25] and [26], an increase in the temperature results in sufficient energy for molecular mobility of the gum leading to decrease in the viscosity. This behavior may be attributed to the thermal degradation of high molecular weight gums into gum with varying molecular weight [27]. Results suggest maximum viscosity of the CG for the various particle size were obtained at agitation speed of 500 rpm.

Effect of replacing MG with CG on the viscosity, specific gravity and pH of gum blend. Table 3 indicates the effect of replacing MG with CG on the physicochemical properties of various gum blends. Figures 5–7 illustrate the effect of replacing MG with CG on the viscosity, specific gravity and pH of the blended gum respectively. The replacement of MG with CG from 0-50 % resulted in a decrease in the specific gravity 1.06–1.02 (3.77 %) and viscosity from 5.91 to 4.65 Ns/m^2 (21.32 %) while the pH increased from 4.4–5.5 (20 %).

From Figure 5 as the MG was replaced up to 50 wt. % CG at interval of wt. 10 %, the viscosity of the blended gum experienced a decrease from 5.91 to 4.65 Ns/m^2. This reduction in the viscosity indicates that the CG acts as a diluting agent since it decreases the thickness/viscosity of the MG. It was also observed that the measured specific gravities varied insignificantly with a slight decrease compared to the MG as indicated in Figure 6. Whereas Figure 7 shows that as the MG was gradually replaced with CG from 0–50 wt. %, an increase in the pH from 4.4 to 5.5 was observed. This is an indication that the inclusion of CG significantly influenced the acidity of the gum blended by 20 % as the CG was increased 0 to 50 wt. %.

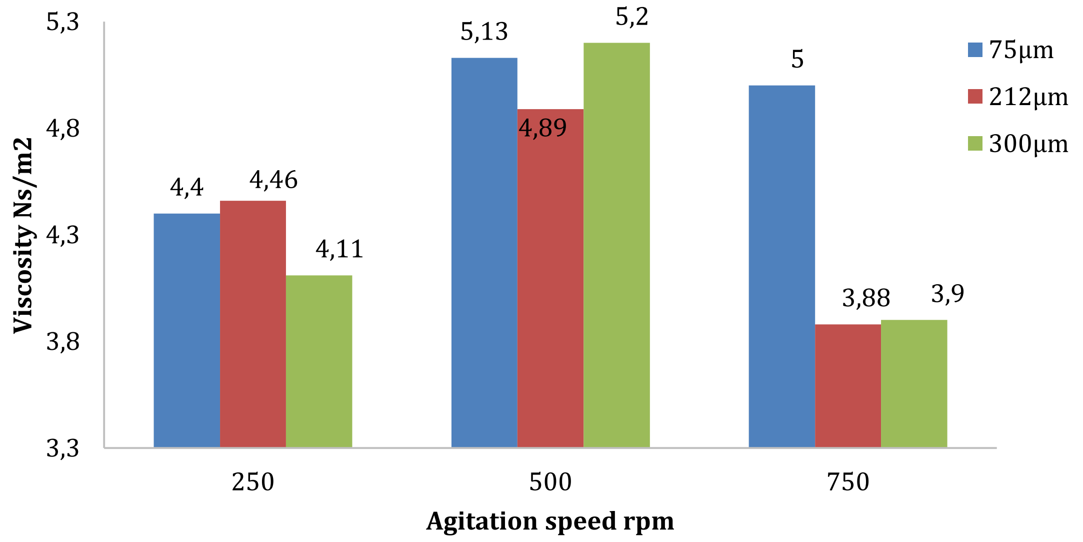

Figure 2 – Variation in the agitation speed on the viscosity of CG at various particle sizes

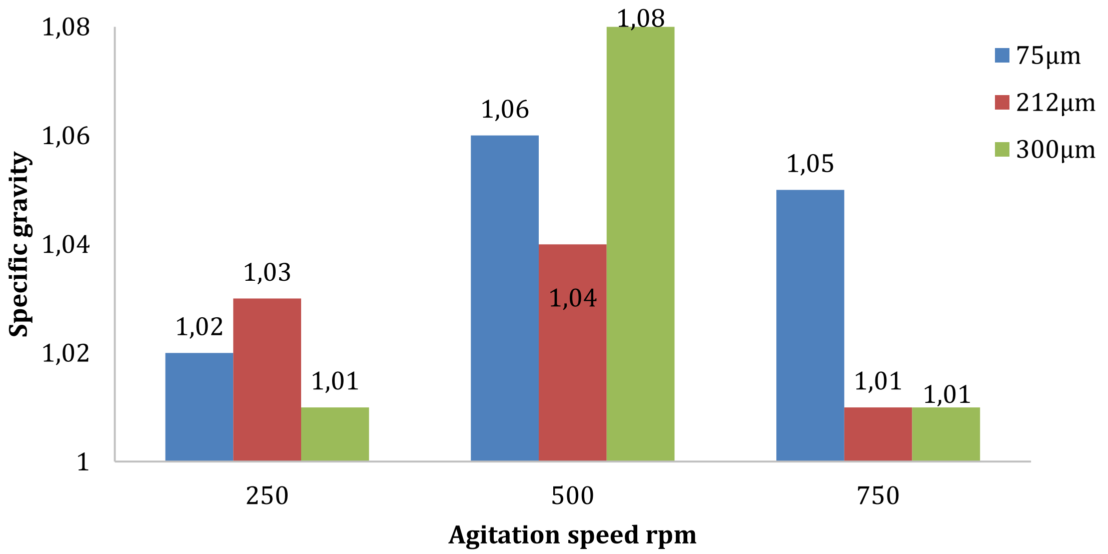

Figure 3 – Variation in the agitation speed on the CG specific gravity at various particle size

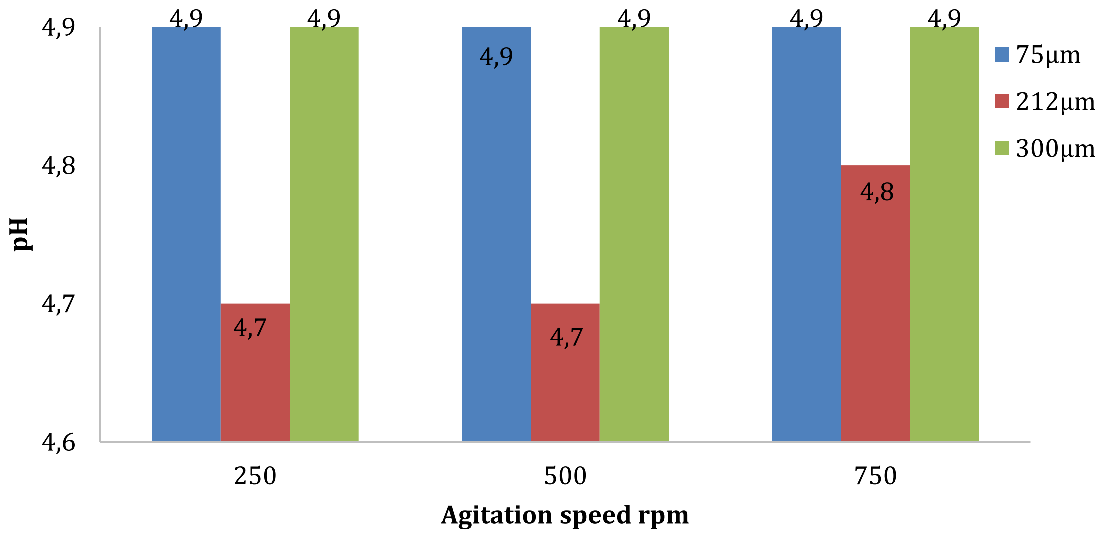

Figure 4 – Variation in the agitation speed on the pH of CG at various particle size

Table 3 – Effect of replacing MG with CG on the physicochemical properties of blended gum

Sample	MG wt. %	Replacement with CG wt. %	Viscosity, Ns/m²	Specific gravity	pH
A1	100	0	5.91	1.06	4.4
A2	90	10	5.84	1.06	4.4
A3	80	20	5.63	1.05	4.5
A4	70	30	5.32	1.03	4.7
A5	60	40	4.76	1.02	5.2
A6	50	50	4.65	1.02	5.5

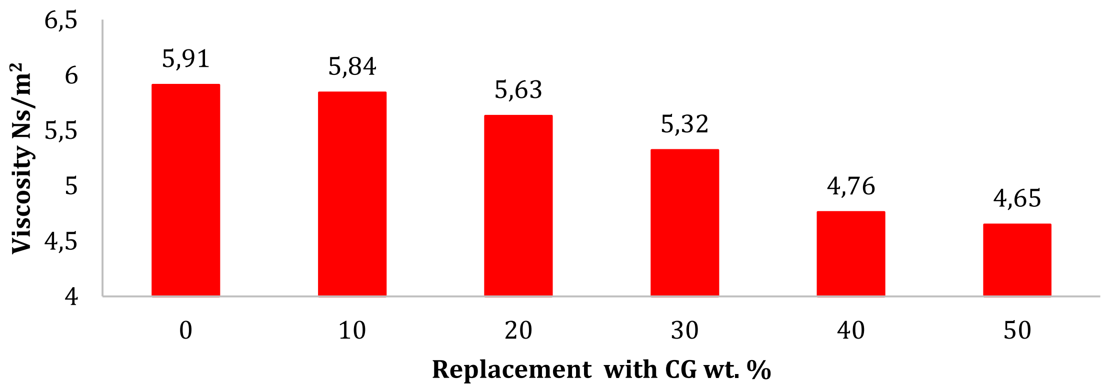

Figure 5 – Effect of Replacement of MG with CG on the viscosity of gum blend

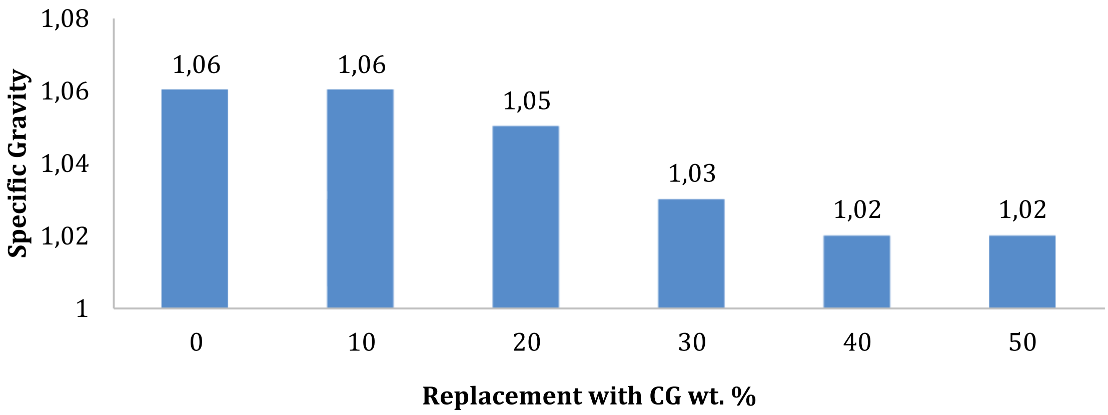

Figure 6 – Effect of Replacement of MG with CG on the specific gravity of gum blend

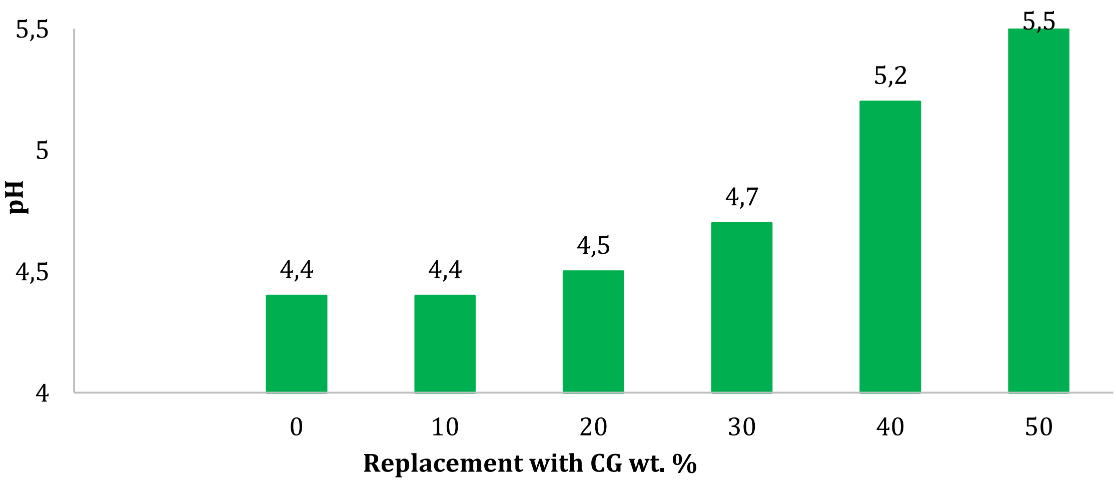

Figure 7 – Effect of Replacement of MG with CG on the pH of the gum blend

Replacement between 0–30 wt. % were found to give the best samples because their pH fell within the pH of Acacia Senegal i.e. 3.9–4.9 [18] and possessed satisfactory viscosities. The best gum blend was observed to be 30 wt. % CG replacement with viscosity of 5.32 Ns/m^2 and pH of 4.7 whose pH fell within the range of 3.9–4.9.

Variation of different composition of Gum Additives. Tables 5–7 indicate the variation of different composition of Glycerine, Starch and Zinc Oxide contents on the viscosity, specific gravities and pH of MG, CG and MG-CG blend respectively whereas Figures 8, 9 and 10 show the influence of varying different composition of glycerine, starch and zinc oxide on the binding properties of various gums such as viscosity, pH and specific gravity respectively.

Table 5 – Variation of different composition of Glycerine, Starch and Zinc Oxide on the viscosities of various gums

% Additive	5 wt.%	7 wt.%	10 wt.%	12 wt.%
Mango gum with Glycerine Ns/m^2	4.30	4.45	4.60	5.10
Cashew gum with Glycerine Ns/m^2	3.00	3.40	4.40	4.70
Mango gum with Starch Ns/m^2	4.90	5.20	5.30	5.70
Cashew gum with Starch Ns/m^2	3.80	3.80	3..95	4.10
Mango gum with ZnO Ns/m^2	3.50	3.60	3.80	3.90
Cashew gum with ZnO Ns/m^2	3.50	3.60	3.75	3.80
Mango/cashew gum with Glycerine Ns/m^2	4.30	4.55	4.80	5.10
Mango/Cashew gum with Starch Ns/m^2	3.85	3.90	3.95	4.00
Mango/Cashew gum with ZnO Ns/m^2	3.40	3.80	4.70	5.00

Table 6 – Variation of different composition of Additives on the specific gravity of various gums

% Additive	5 wt.%	7 wt.%	10 wt.%	12 wt.%
Mango gum with Glycerine	1.08	1.07	1.07	1.06
Cashew gum with Glycerine	1.08	1.07	1.07	1.06
Mango gum with Starch	1.05	1.06	1.06	1.06
Cashew gum with Starch	1.06	1.06	1.06	1.06
Mango gum with ZnO	1.08	1.08	1.07	1.06
Cashew gum with ZnO	1.07	1.07	1.06	1.06
Mango/Cashew gum with Glycerine	1.08	1.06	1.06	1.04
Mango/Cashew gum with Starch	1.08	1.07	1.06	1.06
Mango/Cashew gum with ZnO	1.08	1.08	1.06	1.05

Table 7 – Variation of different composition of Additives on the pH of various gums

% Additive	5 wt.%	7 wt.%	10 wt.%	12 wt.%
Mango gum with Glycerine pH	3.5	3.5	3.4	3.4
Cashew gum with Glycerine pH	3.4	3.5	3.5	3.5
Mango gum with Starch pH	4.0	3.9	3.9	3.8
Cashew gum with starch pH	3.5	3.4	3.4	3.4
Mango gum with ZnO pH	6.5	6.4	6.2	6.2
Cashew gum with ZnO pH	6.5	6.4	6.4	6.4
Mango/ Cashew gum with Glycerine pH	3.4	3.5	3.5	3.6
Mango/ Cashew gum with starch pH	3.6	3.6	3.4	3.4
Mango/ Cashew gum with ZnO pH	6.4	6.4	6.4	6.4

Variation of different composition of glycerine. An increase in the gum's viscosity from 4.30 to 5.1 Ns/m^2, 3.0 to 4.70 Ns/m^2 and 4.30 to 5.10 Ns/m^2 were observed in Figure 8 as the glycerine content was increased from 5-12 wt. % for MG, CG and MG-CG respectively. This increase could be attributed to the glycerine slipperiness which facilitates easy spread of the gum. It was also observed that an increase in the glycerine percentage additive resulted in a decrease in its pH from 3.5 to 3.4 for MG, while CG and MG-CG blend experienced an increase in the pH from 3.4 to 3.5 and 3.6 respectively.

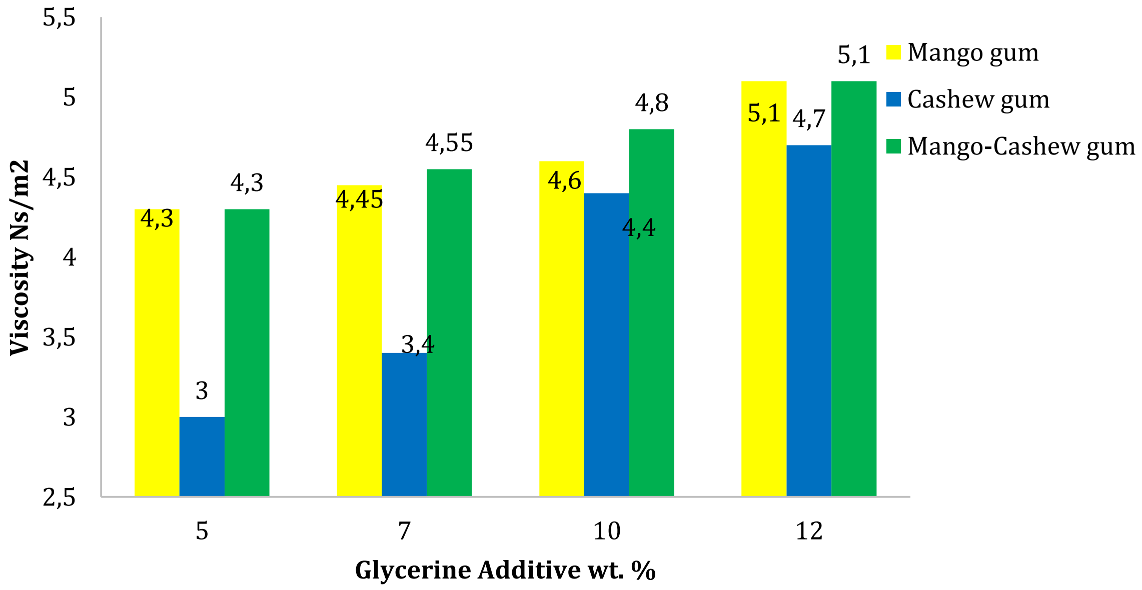

Figure 8 – Variation of different composition of glycerine on the viscosity of various gum

Similar trend of an increase in pH by CG and MG-CG blend were observed by authors [2, 24]. Figure 8 illustrates a steeper rate of the viscosity for CG compared to MG and MG-CG blend as the glycerine was increased from 5-12 wt.%. The MG-CG blend and MG produced the most viscous gum compared to CG as the glycerine was increased by 56.7%, despite the fact that CG's viscosity was significantly improved compared to MG (18.6 %) and MG-CG blend (11.6 %). All gums became more viscous as the glycerine content was gradually increased.

Effect of Starch addition. Figure 9 indicates an increase in the viscosity of the various gums as the starch content was gradually increased resulting in a more viscous gum. The MG was found to be more viscous compared to CG and MG-CG blend by the inclusion of starch from 5–12 wt. %.

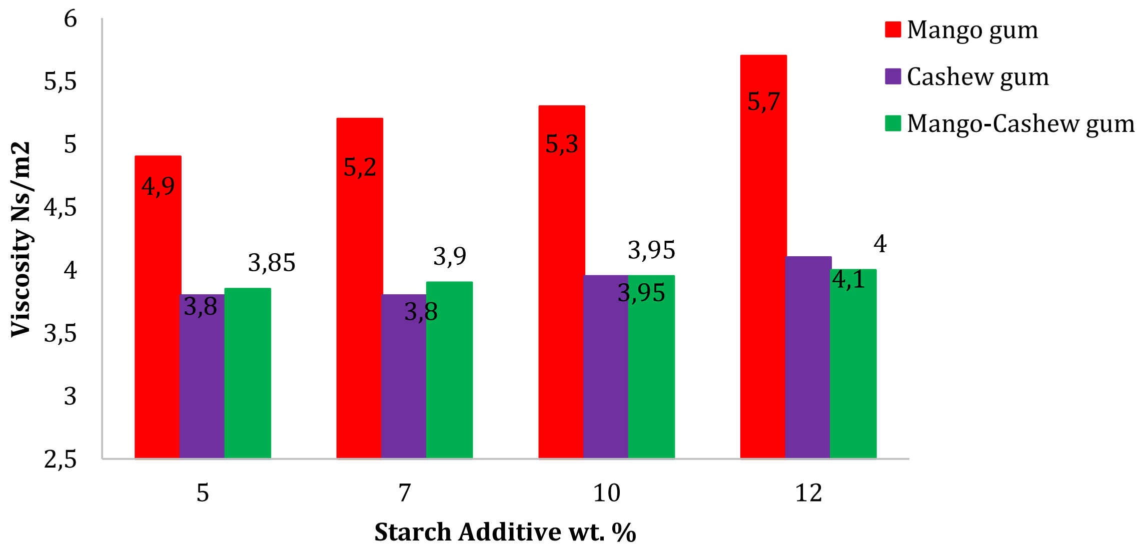

Figure 9 – Variation of different composition of Starch on the viscosity of various gums

Similar trend of an increase in their viscosities as the starch content was increased were observed with the raw CG from [2, 24] respectively and suggested that starch acts as a binding agent, thus, increasing the gum's thickness as starch content was increased. An increase in starch content resulted in a decrease in the pH from 4–3.8, 3.5–3.4 and 3.6–3.4 for MG, CG and MG-CG blend respectively. It was also seen that measured specific gravities of MG slightly increased from 1.05-

1.06 while CG showed no significant change at 1.06 which was similar to [24] whose specific gravity remained constant whereas MG-CG blend decreased from 1.08 – 1.06 as the starch content was gradually increased.

Variation of different composition of Zinc Oxide ZnO. An increase in ZnO from 5–12 wt. % to the various raw gum led to a decrease in the specific gravities of the various gum from 1.08–1.06, 1.07–1.06 and 1.08–1.05 for MG, CG and MG-CG blends respectively. It could also be observed that MG-CG blend indicated a significant reduction in its specific gravity (1.85 %) compared to MG (0.93 %) and CG (0.93 %). Similarly, the viscosities of MG, CG and MG-CG blend increased from 3.5–3.9, 3.5–3.8 and 3.4–5.0 Ns/m^2 as the ZnO content was increased. The MG-CG blend experienced a significant increase in the viscosity by 50 % compared to other gums as seen in Figure 10.

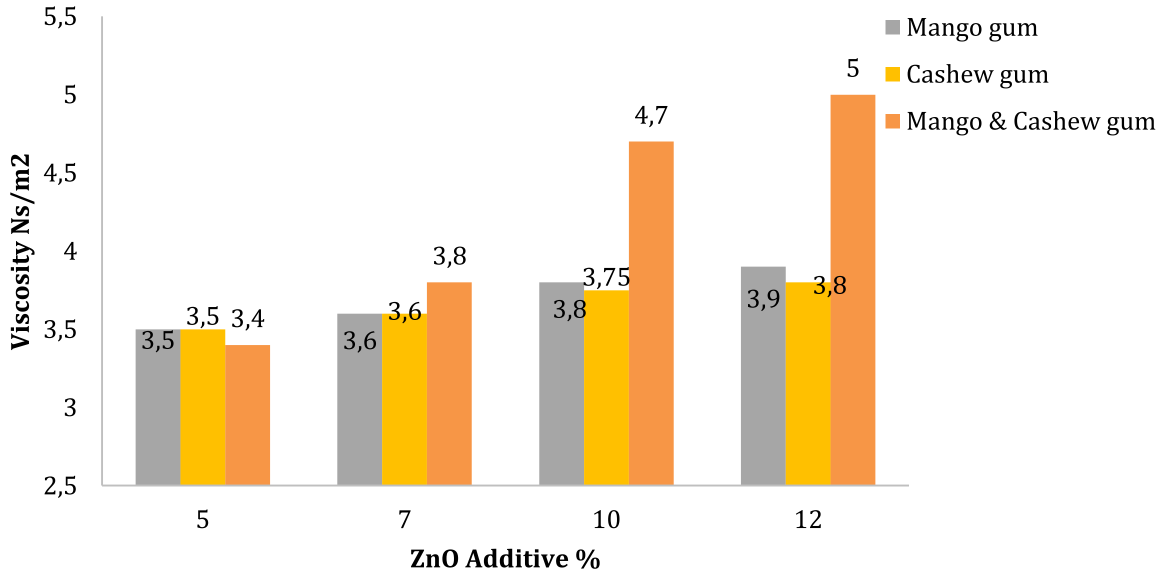

Figure 10 – Variation of different composition of Zinc Oxide addition on the viscosity of various gum

Similar trend of an increase in viscosity of the raw CG was observed by [2] and suggested that ZnO acted as filtering agent to the gum. The pH of the gum experienced a slight decrease as the ZnO was gradually increased for MG and CG whereas MG-CG experienced no significant change in its pH of 6.4. It could be concluded that ZnO inclusion tend to control the acidity of the gum as a stabilizer.

CONCLUSION

The potentials of gum obtained from mango tree latex was investigated and found to possess binding properties similar to cashew gum. The use of additives such as glycerine, starch and ZnO significantly enhanced the gum physicochemical properties. The effect of agitation speed, particle size of the raw CG as well as the replacement of MG with CG were investigated on the viscosity, pH and specific gravity of the blended gum. As the agitation speed was increased from 250 to 500 rpm, all particle size of the gum experienced an increase in their viscosities whereas, when the agitation speed was tripled, only particle size of 75 μm experienced an increase in the gum viscosity while the other particle sizes led to a decrease in the viscosity of the gum. The specific gravity of the gum experienced a similar trend as the viscosity as the agitation speed was increased. The replacement of MG with CG from 0–50 % led to a decrease in the viscosity and specific gravity from 5.91–4.65 Ns/m^2 and 1.06–1.02 respectively, while the pH acidity diminished as the MG was replaced with CG from 4.4 to 5.5. An increase in the glycerine content from 5-12 wt.% resulted in an increase in the viscosities of MG, CG and MG-CG by 18.61 %, 56.67 % and 18.61 % respectively. This increase in the viscosity could be attributed to the easy spread of the gum. The pH showed no significant change, while the specific gravity of the gum significantly diminished as the glycerine content was increased especially for MG-CG. An increase in the starch content led to an increase in the viscosity of the gum especially MG compared with other gums. Whereas, their pH become slightly more acidic as starch content was increased while the specific gravity of MG slightly increased, CG was constant and MG-CG diminished as the starch content was increased. An increase in the ZnO content resulted in a decrease in the specific gravity of the various gums, whereas the viscosity of the various gums increased especially MG-CG blend. This increase could be attributed to the fact that ZnO acts as a filtering agent to the gum. No significant change in the pH was observed as ZnO was increased while the pH of MG and CG experienced a slight decrease i.e. more acidic.

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CONFLICT OF INTEREST

The authors declared that they have no conflict of interest.

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