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Effect of Addition Xanthan gum, Guar gum and Arabic gum on Thermal and Rheological Properties of Brown Rice Batter

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Abstract : The objective of this study was to determine the effect of adding xanthan gum, guar gum and Arabic gum by addition percentages (0.5%, 1%, 1.5%, and 2%) individually on thermal and rheological properties of brown rice batter. Thermal properties were performed by using Differential Scanning Calorimetry (DSC) and viscoelastic behaviour by using Rheometer to assess storage modulus, loss modulus and flow behavior. The result of the study indicated that no significant differences ($p < 0.05$) on T_o and ΔT by adding gums. T_p increased significantly ($p < 0.05$) by 1% guar gum while no significant variations ($p < 0.05$) on it by the addition of xanthan and Arabic gum. T_{end} differed significantly ($p < 0.05$) by 0.5% xanthan and 1% guar. Enthalpy (ΔH) increased significantly ($p < 0.05$) by adding 2% Arabic gum. Furthermore, the addition of xanthan and guar gum increased brown rice batter viscosity significantly ($p < 0.05$) while adding Arabic gum by more than 0.5% made the viscosity decrease ($p < 0.05$). Storage modulus dropped by the addition of xanthan, Arabic gum, and 0.5% guar gum. Moreover, loss modulus decreased significantly ($p < 0.05$) by Arabic gum and 0.5% xanthan, but it grew up ($p < 0.05$) by 2% xanthan. Addition of guar gum made storage and loss moduli higher compared with xanthan and Arabic gum. Adding gum increased the consistency index significantly ($p < 0.05$), while flow index decreased significantly ($p < 0.05$) by 1.5% and 2% gum (xanthan, guar and Arabic).
Key words: brown rice batter, thermal, rheological properties, starch gelatinization, xanthan, guar, Arabic gum.

Introduction

Rice proteins do not possess the visco-elastic properties that is found in gluten, so the rice flour is unsuitable for the production of baked products[1]. Gums and hydrocolloids are used as gluten replacements for producing structure and gas-retaining capacity to rice batters[1]. Also, hydrocolloids are usually added on doughs to improve the structure, mouthfeel, acceptability, and shelf-life of gluten-free products[2].

Starch and hydrocolloid combinations have been widely used in the food industry[3,4,5]. Native starches do not have perfect properties for food products preparation, such as having retrogradation and exhibiting breakdown, either from extended cooking, high shear or acidic conditions, producing weak bodied, rubbery pastes, and undesirable gels, so using combinations of starch and hydrocolloid is necessary for making good products[3,5]. Guar gum, locust bean gum, alginates, carrageenans, and xanthan gum are the most hydrocolloids frequently employed as stabilisers in food industry[6].

Hydrocolloid affects the thermal properties of starch in different ways; this fact can be attributed to some factors such as the ionic charges of both starches and hydrocolloids and molecular structure of hydrocolloids. Generally, hydrocolloids can be interacted with the starch to produce an increase or reduce of the gelatinisation temperatures, depending on type of the hydrocolloid[7]. In general, hydrocolloids can be interacted with the amylose outside the starch granule to provide a complex matrix surrounding the gelatinised granules; consequently, the heat transfer coefficient and rheological properties could be altered[8]. The mixtures of hydrocolloids and starch have been used for modifying and controlling textural and rheological properties, improving moisture retention, controlling water mobility, and maintaining overall product quality during processing and storage[3]. The molecular and chain conformation of polysaccharides for hydrocolloid structure is responsible for an improvement in the viscoelastic properties of dough by integration of hydrocolloids[9]. For example, Guar gum have interesting properties for improving textural and rheological properties of food products and moisture retention capacity[7]. Thus, the purpose of this study was to determine the effect of adding xanthan gum, Guar gum, and Arabic gum by different percentages (0.5%, 1%, 1.5%, and 2%) individually on thermal and rheological properties of brown rice batter.

Materials and methods

Materials:

Local Malaysian brown rice flour was obtained from Jabi Rice Mill Sdn. Bhd. (Kedah) in March 2014), salt (Seng Hin Brothers Enterprises Sdn. Bhd), sugar (Kilang Gula Felda Perlis Sdn. Bhd.), and corn oil (Yee Lee Edible Oils Sdn. Bhd.) were obtained from the local market. Xanthan gum: from *Xanthomonas campestris* (SIGMA) USA. Guar gum: food grade guar gum (HIGUM 4500F) Arabic gum: Acacia Senegal. Manufactured by Pengeluar: Nature Gums/ SUDAN. Packed by/ Pembungkus: Sidratul Corporation Sdn Bhd Malaysia.

Preparing the batter

The batter was prepared by 150 g brown rice flour, 3 g sugar, 3 g salt, 6 g corn oil, gum, and water. All dry ingredients were mixed in a mixer for 30 seconds; the oil was added and mixed for 20 seconds. Water was added and mixed until all ingredients were fully mixed; the mixing process was continued for 10 min and proofing time 30 min at 30 ºC, relative humidity 85%.

Differential scanning calorimetry measurements (DSC):

DSC measurements of samples were recorded on (DSC 822E Mettler Toledo). The method by (Sciariniet al.,)[10] was performed as follows: the dough was prepared as bread making without yeast. 30mg of dough was weighed and put into the pan, then heated from 30-110ºC using a heating rate of 5ºC/ min for determining gelatinisation temperature (T_{onset}, T_{peak} ,T_{end}) and enthalpy ΔH.

Degree of gelatinisation

Degree of gelatinisation was determined according to (Xue et al.,)[11]. Thin layer of dough was put in a conical flask and heated in water bath at 80ºC for one hour; than the sample was cooled immediately to stop the reaction of gelatinisation. Heated dough was mixed with distilled water (1:3) and put in the DSC pan. The pan heated from 30- 120ºC by the heating rate of 5ºC/ min. The degree of starch gelatinisation was calculated by the following equation:

$$\text{Degree of gelatinisation} = \frac{\Delta \mathrm{Ha} - \boldsymbol{\Delta H}\mathrm{b}}{\boldsymbol{\Delta H a}}$$

ΔH a: enthalpy of non- heated dough

ΔH b: enthalpy of heated dough

Rheological measurements

The dough was prepared at same conditions of making bread without adding yeast; the sample was loaded on Rheometer (Physica MCR 301) using parallel plate PP50. The gap size was 1000μm, and the dough was rested 5 min for relaxation of residual stresses; frequency sweep was 0.1-10 HZ and strain 0.1%[1]. The linear viscoelastic region was identified previously at strain 0.01-100% with constant frequency of 1 HZ[12]. Flow behaviour was measured at shear rate 0.3-300 1/s[13]

Result and Discussion

Thermal properties of brown rice batter:

Table (1) presents the effect of adding three types of gum (xanthan gum, Guar gum and Arabic gum) by four different percentages for each one (0.5%, 1%,1.5 %, 2%) on starch gelatinisation temperature [onset temperature (T_o), peak temperature(T_p), end temperature (T_{end})], enthalpy(ΔH), range of starch gelatinisation (ΔT), and degree of glatinization(DG) of brown rice batter compared with brown rice batter without gum.Similar percentages of gums were used by ((Torres et al.[7] and Moreira et al.[14]). No significant differences ($p < 0.05$) were found on onset temperature (T_o), degree of gelatinization(DG), and range of starch gelatinisation (ΔT) between brown rice batter with different percentages of gums and brown rice batter without gum. However, peak temperature increased significantly ($p < 0.05$) by adding 1% Guar gum while no significant differences on peak temperature were found between brown rice without gum and brown rice batter with gum (xanthan, Arabic gum and Guar gum (0.5%, 1.5%, 2%). There were significant differences ($p < 0.05$) on end temperature between brown rice batter with 0.5% xanthan and brown rice batter with 1% guar, while no significant differences ($p < 0.05$) on it between the rest of the samples. Also, adding 2% Arabic gum increased enthalpy (ΔH) and differed significantly ($p < 0.05$) with [(1%, 1.5% xanthan), (1.5%, 2% guar), and (0.5%, 1% Arabic)] which did not have a significant influence on enthalpy with brown rice batter without gum. (Krüger et al.[8]) stated that the addition of gum did not have a significant influence on gelatinisation temperatures. Pongsawatmanit et al.[15] found that the gelatinisation temperature of Tapioca starch slightly shifted to be higher with an increasing Xan content ($p < 0.05$). However, Mandala & Bayas[16] had similar results of this study, where they stated that gelatinisation temperature (onset, peak and conclusion temperature) was not modified by the addition of hydrocolloids. Also, Šubarić et al.[6] found that the gelatinisation temperature did not vary significantly ($p < 0.05$) in starch-hydrocolloid systems, and they found the addition of Guar gum and locust bean gum to starches caused a decrease in gelatinisation enthalpy values. In addition, Torres et al.[7] stated that hydrocolloids can be interacted with the starch to produce an increase or decrease of the gelatinisation temperatures, depending on the type of hydrocolloid, also they found that the values of gelatinisation enthalpy showed a significant increase with increasing Guar gum content.Probably, The results of this study attributed to the strong effect of brown rice flour structure and properties such as water holding capacity on thermal properties of the batter more than gums effect. Hence, no strong significant influence was found for adding gum. As a result, the effect of gum addition on thermal properties will be depending on the type of gum and the type of flour or starch used to prepare the batter.

Table (1) effect adding gum on thermal properties of brown rice batter (with and without gum

Sample	Onset T_o	Peak T_p	Endset T_{end}	Enthalpy ΔH	ΔT	D.G*
Non gum	73.41±0.2286 ^{a}	77.336±0.1939 ^{b}	81.01±0.3808 ^{ab}	-0.377±0.1184 ^{abcd}	7.93±0.2858 ^{a}	0.007±0.3263 ^{a}
Xan.0.5%	73.315±0.2757 ^{a}	77.065±0.120^{b}	80.305±0.176 b	-0.465±0.063 ^{bcd}	6.99±0.0989 ^{a}	-0.39±0.176 a
Xan.1%	72.68±0.0565 ^{a}	77.24±0.00 ^{b}	81.03±0.0141 ^{ab}	-0.600±0.0282 ^{dc}	8.35± 0.707^{a}	0.122±0.123 ^{a}
Xan.1.5%	73.42±0.0989 ^{a}	77.32±0.2404 ^{b}	80.94±0.183 ^{ab}	-0.605±0.0212 ^{dc}	7.52±0.282 ^{a}	0.049±0.045 ^{a}
Xan.2%	73.23±0.1131 ^{a}	77.175±0.1343 ^{b}	80.75±0.325 ^{ab}	-0.39±0.0424 ^{abcd}	7.52±0.212 ^{a}	-0.40±0.098 ^{a}
Gua.0.5%	73.38±0.2899 ^{a}	77.485± 0.120^{ab}	81.215±0.134 ^{ab}	-0.275±0.106 ^{abc}	7.83±0.155 ^{a}	-0.42±0.261 ^{a}
Gua.1%	76.29±1.0133 ^{a}	79.855±3.712 ^{a}	82.725± 3.019^{a}	-0.405±0.0070 ^{abcd}	6.43±1.994 ^{a}	0.045±0.190 ^{a}
Gua.1.5%	74.175±1.364 ^{a}	77.55± 0.000^{ab}	81.18±0.395^{ab}	-0.545±0.120 ^{dc}	7.01±1.760 ^{a}	-0.064±0.156 ^{a}
Gua.2%	72.99±0.0212 ^{a}	77.48±0.1131 ^{ab}	81.24±0.381 ^{ab}	-0.58±0.183 ^{dc}	8.245±0.3606 ^{a}	0.235±0.219 ^{a}
Arabic.0.5 %	73.07±0.5939 ^{a}	77.82± 0.127ab	81.375±0.0636 ^{ab}	-0.565±0.162 ^{dc}	8.305±0.530 ^{a}	0.22±0.214 ^{a}
Arabic.1%	74.755± 2.085^{a}	77.52±0.6364 ^{ab}	80.62±1.781 ^{ab}	-0.675±0.403 ^{d}	5.865 ±3.867^{a}	0.28±0.428 ^{a}
Arabic. 1.5%	72.98±0.403 ^{a}	77.39±0.240 ^{b}	81.16± 0.424^{ab}	-0.165±0.007 ^{ab}	8.175±0.0282 ^{a}	-0.086±1.447 ^{a}
Arabic.2%	73.81±0.1838 ^{a}	77.515± 0.0495^{ab}	80.95± 0.212^{ab}	-0.082±0.0014 ^{a}	7.14±0.0282 ^{a}	-3.31±2.425 ^{b}

Data in the same column with different letter differ significantly ($p < 0.05$), non gum: brown rice batter without gum, *D.G: degree of starch gelatinization, ΔT: rang of gelatinization.

Table (2) shows the effect of adding gum on rheological properties of brown rice batter at 1HZ frequency, Viscosity at 300.

Sample	Viscosity Pa.s	Storage modulus G' Pa	Loss modulus G'' Pa	Complex viscosity Pa.s	Tan G''/G'	Complex modulus G*
Non gum	2.397±0.32^{f}	2956.66±420^{a}	383.33±54^{e}	475±68.02^{a}	0.1293±0.00^{f}	2981.41±424^{a}
Xan 0.5%	3.24± 0.54731^{cd}	1886.66±203.059^{de}	312±28.47 ^{f}	304.66±31.65^{d}	0.165±0.004 ^{e}	1912.29±204.85^{ed}
Xan1%	2.88±0.0458 ^{de}	1816.6±15.27^{de}	371.66±61.84 ^{ef}	294±2.08^{d}	0.203±0.203^{c}	1854.93± 21.96^{ed}
Xan1.5%	3.25± 0.0519^{cd}	2153.3±80.21^{cd}	422.33±11.84 ^{de}	349.66± ^{cd}	0.195±0.008 ^{cd}	2194.4±78.84^{cd}
Xan2%	3.44±0.2052 ^{bc}	2270±175.78^{c}	466.66±36.17 ^{cd}	369±28.16 ^{c}	0.205±0.0015^{c}	2317.4±179.43^{c}
Gua0.5%	3.77±0.2179 ^{ab}	2480±252.38 ^{bc}	364±31.32 ^{ef}	399±40.63 ^{bc}	0.146±0.004 f	2506.57±254.18^{bc}
Gua1%	3.81±0.0288 ^{ab}	2763.3±80.208 ^{ab}	499±12.22 ^{c}	447±13.11 ^{ab}	0.180±0.0015 ^{de}	2808.14 ±81.03^{ab}
Gua1.5%	4.033±0.0850^{a}	2693.3±105.98 ^{ab}	615.33±17.03^{b}	439.33±17.15 ^{ab}	0.228±0.0053 ^{b}	2762.75±106.39 ^{ab}
Gua2%	4.2±0.3195 ^{a}	2910±310.96^{a}	746±69.41 ^{a}	478.33±50.52 ^{a}	0.256±0.0043 ^{a}	3004.11±318.39 ^{a}
Arab0.5%	2.69±0.2059 ^{ef}	1853.3±240.1^{de}	251.33±29.48^{g}	297.66±38.18 ^{d}	0.1356±0.0023^{f}	1870.29±241.83^{ed}
Arab1%	1.52±0.297^{g}	1090.3±155.30^{g}	161±23.81 ^{h}	175.33±24.54 e	0.147±0.0035^{f}	1102.15±157.06^{g}
Arab1.5%	1.91±0.120 ^{g}	1543.3±72.34^{ef}	220.66±12.50 ^{gh}	221.66±57.73 e	0.142±0.00351^{f}	1559.03±73.2^{fe}
Arab2%	1.57±0.0264^{g}	1413.3±60.27f^{g}	206.33±7.50 ^{gh}	227.33±9.60^{e}	0.1458±0.00104^{f}	1428.3±60.72^{gf}

Data in the same column with different letter differ significantly ($p < 0.05$), non gum brown rice batter without gum.

Rheological properties of brown rice batter:

Table (2) presents the effect of gum addition (xanthan, Arabic, Guar) by different percentages (0.5%, 1%.1.5%, 2%) on rheological properties (storage modulus G', loss modulus G'', complex viscosity, tan (G''/G') and complex modulus G*, and viscosity at 300 s\1. The addition of xanthan gum and guar gum increased the viscosity significantly ($p < 0.05$), and Guar gum made the viscosity higher. On the other hand, adding Arabic gum more than 0.5% decreased viscosity significantly ($p < 0.05$), while no significant influence ($p < 0.05$) was found by 0.5% Arabic gum. (Mandala &Bayas[16], Kim&Yoo 2006, Wang et al.[18] and Pongsawatmanit et al.[15]) reported that there was anoticeable increase in viscosity due to theaddition of gum. Kim &Yoo[17] found that the enhancements in overall viscosity of starch–gum mixtures was attributed to the increase in gum concentration due to swelling of the starch granules during gelatinisation in starch–galactomannan (guar gum or locust bean gum) composite system, and they stated another explanation that was the increase of viscosity in the starch–xanthan gum mixture is due to the interactions between gelatinised granules enhanced by xanthan. Mandala &Bayas[16] stated that an increase of starch viscosity was due to synergistic interactions of starch and gums; and the synergistic effect between gums and starch was observed because of the variation of polymers' phase separation, rather than due to intermolecular associations. Thus, Arabic gum has high water solubility and low bulk viscosity[19], which may reflect a decrease of the batter viscosity. The addition of xanthan gum (0.5%- 2%), Guar gum 0.5% and Arabic gum (0.5%, 1%, 1.5%, and 2%) decreased storage modulus significantly ($p < 0.05$). However, storage modulus did not influence significantly ($p < 0.05$) by adding guar gum (1%, 1.5%, and 2%). Loss modulus decreased significantly ($p < 0.05$) by adding 0.5% xanthan and Arabic gum (0.5%, 1%, 1.5%, and 2%). On the other hand, the addition of 2% xanthan increased loss modulus significantly ($p < 0.05$), also loss modulus increased gradually ($p < 0.05$) when an increase in percentage of Guar gum from 1% to 2%, while no significant differences ($p < 0.05$) on loss modulus by adding xanthan (1%, 1.5%) and 0.5% Guar. Figure [(1) A, B, C, and D] presents higher storage modulus and loss modulus by adding Guar gum flowing by xanthan gum then Arabic gum. Complex viscosity decreased significantly ($p < 0.05$) by adding xanthan gum and Arabic gum by (0.5% to 2%) and 0.5% guar gum, but no significant variations ($p < 0.05$) were found when adding Guar gum (1%, 1.5%, 2%). Tan value did not affect significantly ($p < 0.05$) by adding Arabic gum (0.5% to 2%) and 0.5% Guar, while tan value increased significantly ($p < 0.05$) by xanthan gum (0.5% to 2%) and Guar gum by (1% to 2%). complex modulus decreased significantly ($p < 0.05$) by adding xanthan and Arabic gum (0.5% to 2%) and Guar by 0.5%. However, the addition of Guar gum by (1%, 1.5%, and 2%) did not influence complex modulus significantly ($p < 0.05$). Hydrocolloids interacted outside the starch granule with the amylose to produce a more complex matrix of amylose and hydrocolloid surrounding the gelatinised starch granules; as a consequence, rheological properties could be modified[8]. Wang et al.[18] found that storage (G') and loss (G'') moduli increased with the increase in xanthan gum concentration that is not the same with the result of this study which indicates that storage modulus decreased by addition percentages of xanthan gum with exception of increasing by 2%, and they stated that the dynamic rheological properties of the mixtures of rice starch–xanthan gum were affected by the addition of gum depending on the gum concentration. Furthermore, Torres et al.[7] demonstrated that Guar gum showed the largest effect on storage modulus when adding it to chestnut flour dough. Moreover, Crockett et al.[20] stated that the increase of elastic moduli was pronounced by adding xanthan gum. Cai et al.[21] found that increasing the apparent viscosity of hydrothermally treated glutinous rice flour by adding xanthan gum due to the synergistic interactions between rice flour and xanthan gum. Shanthilal & Bhattacharya[22] found that the addition of Arabic gum (0% to 5%, w/w) to rice flour dough with moisture contents (44% to 50%) made the rheological parameters changed. Therefore, the effect of adding gums was based on type of gum[23]. perhaps the concentration of gum and the type of flour or starch had impacted role in gum-batter system,for instance, brown rice flour had a big ability of holding water, resulting in dropping of free water for interaction with gum.

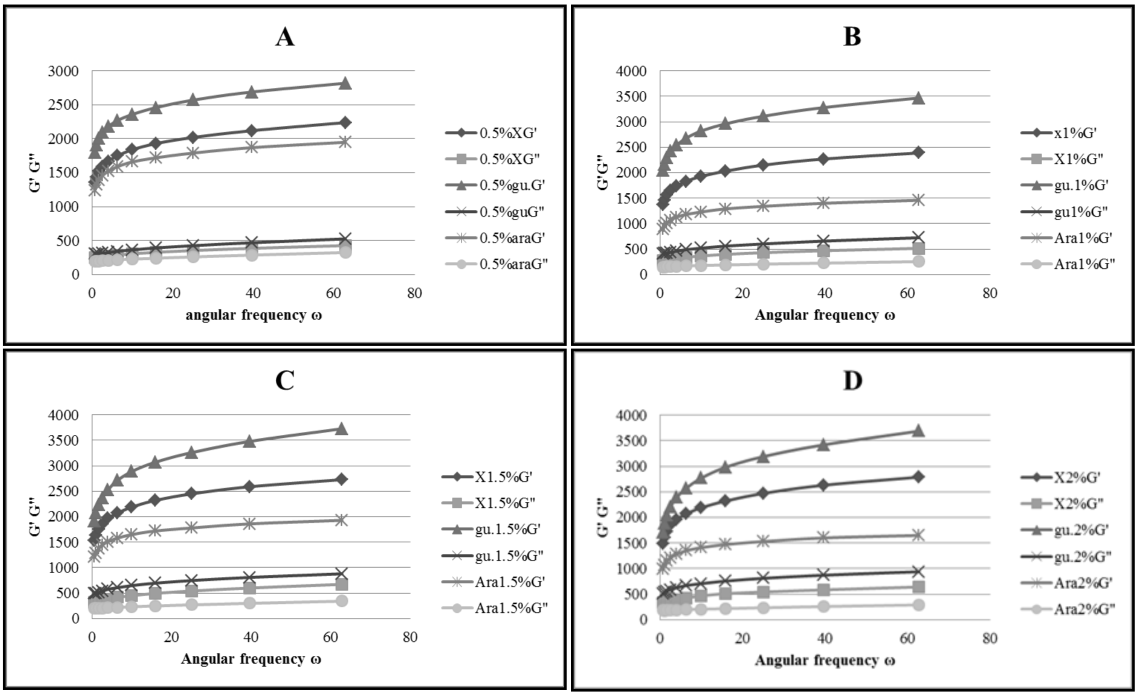

Figure (1) oscillatory shear measurements (storage modulus (G'),loss modulus(G") for xanthan gum, guar gum and Arabic gum [A(0.5% gum), B(1% gum), C(1.5% gum) and D(2% gum)]

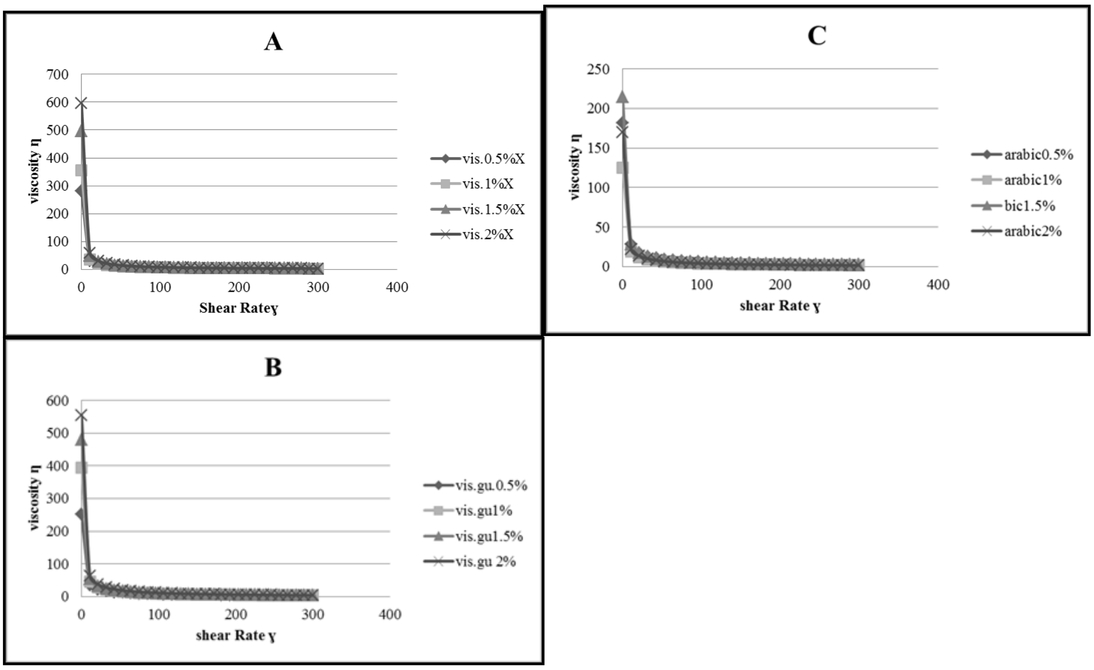

Figure (2) Steady-shear curves of brown rice batter with gum [A (xanthan gum), B (guar gum) and C (Arabic gum)]

From (Fig 2 A, B, and C), the viscosity decreased with an increase shear rate, increasing of shear rate deform and rearrange starch particles lead to lower flow resistance then lower viscosity which indicating the shear thinning behaviour and non-Newtonian character[24]. The flow curve data, as (Fig 3 A, B, and C) showed that brown rice batter with addition of gum were fitted in Ostwald-de Waele model (Eq 1) by high R^2. Brown rice batter without gum had a good fit in the cross model as well.

Ostwald-de Waele model $\sigma = K.\gamma^n$ equation1

Where σ is the shear stress (Pa), γ is the shear rate (s^{-1}), K is consistency index (Pa s^n) and n is flow index (dimensionless).

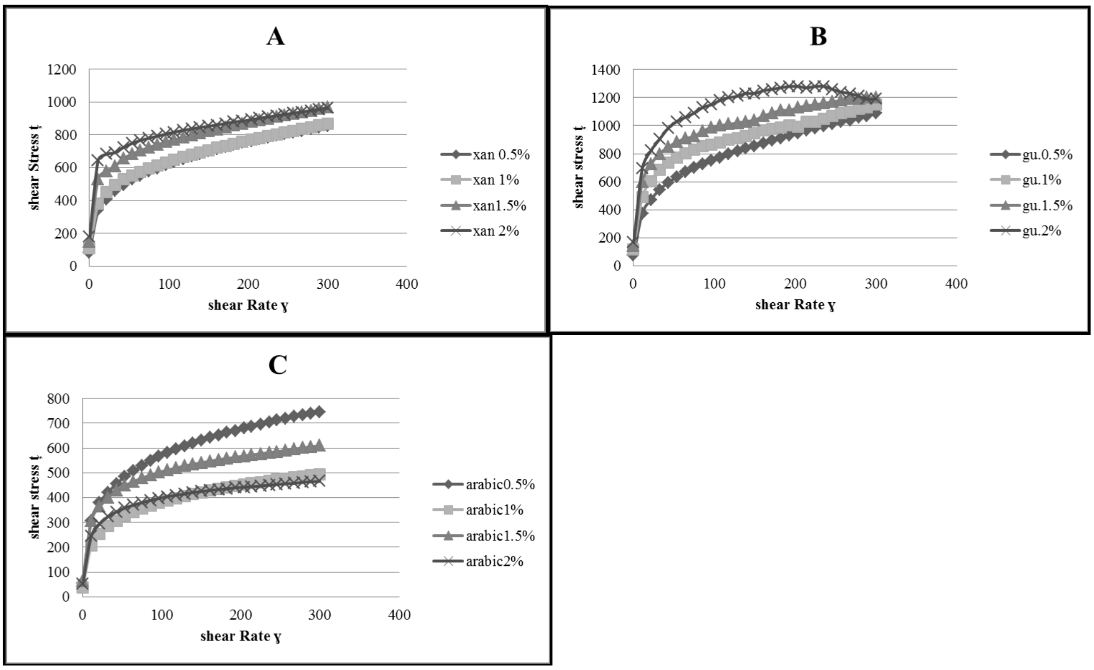

Figure (3) Flow curves of brown rice batter with gum [A (xanthan gum), B (guar gum) and C (Arabic gum)]

Table (3) presents the Ostwald model parameters(consistency index (K) and flow index (n)). Addition of gum (xanthan, Guar, and Arabic) increased the consistency index significantly ($p < 0.05$) with higher value by adding 2% xanthan gum, while no significant influence was found ($p < 0.05$) by 1% Arabic gum. No significant variations ($p < 0.05$) were found on flow index by adding 0.5% xanthan, 1% Guar, 0.5% Arabic, and 1% Arabic. However, the flow index dropped significantly ($p < 0.05$) by an increase of xanthan gum (1%, 1.5%, 2%), Guar gum (1.5%, 2%), and Arabic gum (1.5%, 2%), and the shear-thinning character of xanthan gum (1.5%, 2%) was more pronounced effect than those of other polysaccharide gums. On the other hand, the flow index grew up by an addition of 0.5% Guar gum to be a higher value compared with other gums. Kim &Yoo[17] found that rice starch–xanthan gum mixtures had high shear-thinning flow behaviour, and the consistency index (K) increased with an increase in xanthan gum concentration which was the same with the results of this study. Moreira et al.[2] found that the flow index of chestnut flour dough increased significantly by using different hydrocolloids (Guar gum, hydroxypropyl methyl cellulose (HPMC), or tragacanth gum), and slight variations with increasing hydrocolloid content were observed.

Table (3) Ostwald model parameters of brown rice batter with and without gum

Sample	Consistency index K	Flow index n	R^2	Standard deviation
Non gum	104.79±5.868 ^{i}	0.324±0.0084 ^{b}	0.999	0.930
Xan.0.5%	169.735±6.682 ^{g}	0.292±0.0068 ^{b}	0.999	0.8560
Xan. 1%	214.613±2.890 ^{f}	0.238±0.00113 ^{c}	0.999	0.7516
Xan.1.5%	367.69±9.156 ^{c}	0.1552±0.0114 ^{d}	0.967	5.123
Xan. 2%	509.97±20.57 ^{a}	0.107±0.0244 ^{e}	0.976	5.6123
Guar 0.5%	160.167±6.067 ^{g}	0.359±0.0183 ^{a}	0.999	2.0504
Guar 1%	235.367±3.779 ^{e}	0.3072±0.0067 ^{b}	0.999	4.2665
Guar 1.5%	318.76±5.787 ^{d}	0.257±0.0022 ^{c}	0.995	6.946
Guar 2%	401.16±21.89 ^{b}	0.2476±0.00431 ^{c}	0.997	5.557
Arabic 0.5%	154.26±5.342 ^{g}	0.302±0.0166^{b}	0.999	2.443
Arabic 1%	94.166±9.008 ^{i}	0.2958±0.0159 ^{b}	0.999	1.1554
Arabic 1.5%	171.873±9.60 ^{g}	0.234±0.0247 ^{c}	0.999	3.857
Arabic 2%	132.413±2.96 ^{h}	0.255±0.0668^{c}	0.995	3.0830

Data in the same column with different letter differ significantly ($p < 0.05$), non gum brown rice batter without gum.

Conclusion:

Addition of gum to brown rice batter altered thermal and rheological properties in different ways based on the type and additional percentage of gum. Furthermore, the gum reaction with brown rice batter was different in some parameters (enthalpy, storage, and loss moduli) which had already been determined by previous studies by using the same gum with different types of flour or starch. The viscosity increased gradually with the increase of adding the percentage of gum, by an exception with Arabic gum. More shear thinning behaviour by a decrease of flow index was observed by adding percentage of gum (1.5%, 2%). Gum addition did not have a big effect on thermal properties of brown rice batter.

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