academicJournals

Vol. 11(8) pp. 263-272, August 2017
DOI: 10.5897/AJFS2017.1596
Article Number: AC2C21E65183
ISSN 1996-0794

http://www.academicjournals.org/AJFS

African Journal of Food Science

Full Length Research Paper

Effect of blending ginger starch (*Zingiber officinale*) on the dynamic rheological, pasting and textural properties of rice flour

Janet Quaisie*, Luyan Liao and Weiguo Wu

Department of Food Science and Technology, Hunan Agricultural University Changsha, Hunan, China.

Received 22 March, 2017; Accepted 16 June, 2017

Rice flour (RF) was blended with ginger starch (GS) (*Zingiber officinale*) at various concentration levels (0, 20, 40, 60, 80 and 100%) and compared with that of cassava starch (CaS). The dynamic rheological, pasting and textural property effects of these starches on RF were studied. CaS and GS and their blends with RF all exhibited a weak gel behavior as shown by their dynamic moduli (G' and G") values. The higher tan δ (0.45 and 0.51) values recorded by GS and CaS respectively raised the tan δ values in their blends with RF thereby reducing the elasticity of RF. The rapid visco analyzer (RVA) results revealed that, GS exhibited the appropriate characteristics for noodle processing in most of the pasting properties as compared to CaS such as; higher trough viscosity (165.05 RVU), final viscosity (241.20 RVU) and lower swelling power (13.17 g/g). CaS gets to be selected over GS for energy conservation during cooking since it recorded a lower pasting temperature of 70.90°C likewise its formulated blends with RF. Measurement of textural property demonstrated that, the hardness and chewiness of RF could be increased (101.25-293.34 g and 47.34-72.19) respectively by blending with GS. Also, the cohesiveness of RF got to be reduced (0.51-0.27) by the addition of GS. The various properties of GS and its effect on RF blends unveiled in this study makes GS fit to be considered in the modification of rice flour for noodle production.

Key words: Rice flour, ginger starch, cassava starch, formulated blends, physiochemical properties.

INTRODUCTION

Rice flour is one of the basic ingredients in the production of various food products. However, rice noodles stand out to be the most favorably consumed by many people in South Asian countries, and China is no exception (Qazi et al., 2014). Apart from the variations in the technology of production, instability of the quality of rice being the raw materials used also adds to the drawbacks on the noodle product's qualities (Surojanametakul et al., 2002).

*Corresponding author. E-mail: 120425073@qq.com.

The structural network of noodle products is mainly determined by the starch content of the rice noodle due to the absence of gluten in rice flour (Yoenyonbuddhagal and Noomhorm, 2002; Qazi et al., 2014). Therefore, combination of different starches have been used for noodles preparation, such as corn and potato starches, maize and tapioca starches (Kasemsuwan et al., 1998; Kaur et al., 2005) respectively. The replacement of rice flour with various starches such as cassava starch, potato starch and corn starch had various characteristics upon the type/amount of starch added (Surojanametakul et al., 2002). Since starch from different plant source varies in appearance, composition, as well as properties, due to its morphology and physiochemical properties, there is the need to continue the search for starch with excellent properties from both conventional and non-conventional sources (Kolawole et al., 2013). Blending of various tropical crop starches such as canna starch, mung bean starch, sweet potato starch, cassava starch, corn starch with rice flour has been studied (Surojanametakul et al., 2002; Thao and Noomhorm, 2012; Qazi et al., 2014). However, starches obtained from many tubers and roots, with few exceptions such as, arrowroot, and ginger have not been commercialized (Peroni et al., 2006). Ginger root (*Zingiber officinale*) is mostly consumed as a delicacy, medicine or spice as well as used in phytotherapy because of its volatile oil and oleoresin. A powdery substance was extracted from ginger roots and upon the physiochemical test performed confirmed the presence of carbohydrate that means starch (Talele et al., 2015). Extraction of ginger starch has received various research attentions (Talele et al., 2015). Also, there are studies on the modification of cassava starch with ginger (Daramola and Osanyinlusi 2006). Ginger starch also compared favorably with maize starch as in physiochemical properties and therefore showed that it has a high potential for industrial applications as biomaterials in composites food, textile and pharmaceutical industries (Afolayan et al., 2014). According to a report by Peroni et al. (2006), ginger starch displayed a higher amylose content of 26.5% and therefore makes it fit to be considered in the production of noodles since amylose content of starch/flour used in noodle production has a significant correlation with the noodles quality. However, studies on its applications in the food industry is extensively limited, especially, its use in the modification of rice flour for noodle production. Hence, the need to study and compare its physiochemical effect on the properties of rice flour with that of cassava starch which is already in use. The color, water binding capacity, swelling power and solubility, pasting, textural and dynamic rheological properties of pure rice flour (RF), native cassava starch (CaS), native ginger starch (GS) and the formulated blends were studied. The objective of this research work was to find out whether ginger starch is fit to be used in rice flour modification for noodle production as cassava and other tropical crop starches are already commercialized.

MATERIALS AND METHODS

Commercial native cassava starch (CaS) and sticky milled rice flour (RF) were purchased from Nanjing Ganzhiyuan Sugar Co LTD and Cho Heng Rice Vermicelli factory Co. Ltd (China) respectively. Fresh ginger (*Z. officinale*) was bought from an open market in Changsha City, Hunan province of China and other analytical grade reagents were obtained from Yueyang Hunan Chemical Industry Co. Ltd (China).

Isolation of starch from Ginger (*Z. officinale*)

Native ginger starch extraction was carried out according to the method described by Kolawole et al. (2013) with little modification for larger quantity. Fresh roots of ginger of about 4 kg were peeled and washed. The samples were cut into small pieces and soaked in 4 L of 1% w/v sodium metabisulphite solution at room temperature (25°C overnight (24 h) to aid the release of starch. The pieces of root were removed and wet milled into a slurry using a grater. The paste was dispersed in large volume of 1% w/v sodium metabisulphite solution and filtered through muslin cheese cloth. The filtrate was allowed to stand for 1 h to facilitate starch sedimentation and the top was decanted and discarded. The starch was washed with 2 L of 1% w/v sodium metabisulphite solution and then, the suspension was centrifuged at 3500 rpm for 10 min to facilitate the removal of dirt. The supernatant was carefully decanted and the mucilage scraped off, the process was repeated for five times with the mucilage on the starch scraped continuously until a pure starch was obtained. The resulting starch was dried at 60°C in hot air oven, dry milled, sieved through 80 mesh sieve, weighed and packed in airtight polythene bags then stored in the refrigerator at 4°C.

Proximate analysis of rice flour

The moisture, ash, protein, fat, total sugar and starch contents of rice flour were determined according to methods described in American Association of Cereal Chemists (AACC, 2000).

Blends formulations

Rice flour was blended manually with cassava and ginger starches at ratio levels of 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 (weight basis) and were sieved using 80 mesh sieve in order to obtain granules of uniform sizes. They were packed into an airtight polythene bags and stored in the refrigerator at 4°C until used. The blends of RF and starches were studied for water binding capacity (WBC), swelling power (SP) and solubility (S), pasting, textural and dynamic rheological properties.

Color measurements

The color L* (index of lightness/darkness), a* (index of hue, red/green) and b* (index of hue, yellow/blue) where, L* = lightness (0 = black, 100 = white), a* (-a* = greenness, +a* = redness) and b* (-b* = blueness, +b* = yellowness of pure rice flour (RF), ginger starch (GS) and cassava starch (CaS) were determined using

Chroma meter, CR-400 from Konica Minolta Sensing, INC. (Industrial Instruments), Japan. Three repeated measurements were taken for each of the three replicate (starch/flour) per sample (total of nine readings per sample). The whiteness value was obtained according to Equation (1).

Whiteness = $100 - [(100 - L)^2 + a^2 + b^2]^{\frac{1}{2}}$ (1)

Water binding capacity

Water binding capacity was determined according to the method proposed by Oke et al. (2013). About 2.5 g of the samples (rice flour and starch formulation) was suspendered in 30 ml distilled water at 30°C in a centrifuging tube, shook for 30 min using a water bathing constant temperature vibrator and then, centrifuged at 3000 rpm for 10 min. The supernatant was decanted and the weight of the paste formed was recorded. The water binding capacity (WBC) was then calculated as the paste weight per gram dry sample.

$$\text{WBC} = \frac{\text{Gram bound water}}{\text{weight of dry sample(g)}} \times 100 \quad (2)$$

Determination of swelling power and solubility

Swelling power and solubility of pure rice flour and starches were measured using the method described by Oke et al. (2013) with little modification. Dry sample of 0.5 g was weighed in triplicate and then transferred to a 100 ml conical flask. Exactly 15 ml of distilled water was added and stirred. The sample was transferred into a water bathing constant temperature vibrator then, heated for 30 min at 92.5°C with constant shaking (stiring). The gel formed was transferred into pre-weighed centrifuge tubes and centrifuged at 3500 rpm for 15 min. The supernatant was then carefully poured into pre-weighed petri dishes and the gel sediments in the centrifuge tubes were weighed. The supernatant in the petri dish were evaporated at 130°C for 8 h and weighed again. Swelling power was expressed in g of swollen granules per g of dry starch/flour in the sediments and solubility (%) was expressed as the weight of soluble starch/flour in percent of initial dry starch weight. SP and S were calculated according to Equations 3 and 4.

$$S = \frac{weight\ of\ soluble\ starch/flour}{weight\ of\ sample\ on\ dry\ bases} \times 100 \quad (3)$$

$$SP = \frac{weight\ of\ sedimented\ paste}{weight\ of\ sample\ on\ dry\ bases \times (100 - S)} \times 100 \quad (4)$$

Pasting properties

Pasting properties of rice flour and starch formulations (at different concentrations) were determined according to AACC (2003), using a Rapid Visco Analyzer controlled by Thermocline software for windows (RVA, Model 4D, Newport Scientific, Australia). Sample (3.0 g, 14 g/100 g moisture basis, in triplicate) was weighed directly into the RVA canister and distilled water was added to obtain a total weight of 28 g. The samples were stirred by the paddle in the RVA canister at 960 rpm for the first 10 s then at 160 rpm for the rest of the test. There are five stages of the standard profile; (1) holding for 1 min at initial temperature (50°C), (2) heating to 95°C for over 3.42 min, (3) holding at 95°C for 2.3 min, (4) cooling to 50°C for over 3.48 min and (5) holding at 50°C for 2 min. Each sample was held for 13 min and the interval between viscosity and temperature readings was 4 s. Values measured from the pasting profile were, peak viscosity (PV), trough viscosity (TV), final viscosity (FV), peak time (P_{time}), pasting temperature (P_T) and breakdown. While relative break down, relative set back and pasting time were calculated from the data obtained by RVA using Equations 5 and 6.

$$RBD(\%) = \frac{Break\ down}{Peak\ viscosity} \times 100 \quad (5)$$

$$RSB(\%) = \frac{Set\ back}{Final\ viscosity} \times 100 \quad (6)$$

Texture analysis of RVA gels

Texture analysis as reported by Bhattacharya et al. (1999) was followed with slight modification. The samples prepared in the RVA was poured into small aluminum canisters (37.0 mm diameter and 20.0 mm height) and stored at 2°C overnight for solid gel formation. The aluminum canisters were sealed with paraffin wrap to prevent moisture loss during storage. The solid gel formed was evaluated for their textural properties by texture profile analysis (TPA) using the texture analyzer (TA/XT2*i*, Stable MicroSystems, Surrey, UK) equipped with a Texture Expect Software program (version 5.16). Each canister was placed upright on a metal plate and the solid gel was compressed at a speed of 1.0 mm/s to a distance of 10 mm with a stainless steel punch probe (P/0.5). The compression was repeated twice to generate a force-time curve from which hardness (HD,g), springiness (SP,mm), adhesiveness (AD), cohesiveness (CO), gumminess (GU, g) (hardness × cohesiveness), chewiness (CH, g×mm) (gumminess×springiness) were all computed by the software supplied with the instrument. Three repeated measurements were taken for each of the three replicate gels per sample (total of nine readings per sample). The diameter of the solid gel (37 mm) was divided such that unbiased repeat measurements (with puncture) could be made on different areas of the same solid.

Rheological properties

The rheological properties of rice flour and starch formulations were determined using a rotational rheometer (Physical MCR 301, Anton Paar GmhH Stuttart, Germany) equipped with a cone and a plate geometry sensor (40 mm diameter, 1°cone angle and 0.098 mm gap). Gelatinized samples paste (6% RF:Starch, w/w) were prepared by using the RVA. The gelatinized sample was placed on the determination platform of the instrument and a thin layer of silicon oil was added to prevent water evaporation. The dynamic viscoelasticity was determined in triplicate for each sample.

Dynamic viscoelastic measurements

The dynamic viscoelastic measurements of storage modulus (G') and loss modulus (G") were evaluated by first running deformation sweeps at a constant frequency (10 rad/s) to determine the maximum deformation attainable by a sample in the linear viscoelastic range. Afterwards, by applying a constant strain (0.5%), which was within the range, a dynamic frequency sweep over a frequency range of 0.1 to 10 Hz was performed. The sample measurement temperature was kept constant at 25°C.

Statistical analysis

All experiments and analysis were performed in three replications. The data was subjected to statistical one-way ANOVA test and Duncan multiple range test (DMRT) to compare means at 0.05

Table 1. The color values of pure rice flour, native cassava and ginger starch.

Sample	L*	a*	b*	Whiteness
RF	96.65 ± 0.19[b]	0.37 ± 0.02[b]	2.52 ± 0.02[b]	95.81 ± 0.14[b]
CaS	97.19 ± 0.02[a]	0.11± 0.01[a]	1.71 ± 0.04[c]	96.79 ± 0.04[a]
GS	95.35 ± 0.24[c]	-0.42± 0.04[c]	3.61 ± 0.04[a]	94.09± 0.17[c]

Values represents mean of triplicate determinations ±SD. Different letters within columns represents significant differences (p<0.05). Rice flour (RF), cassava starch (CaS) and ginger starch (GS).

Table 2. Physiochemical properties of rice flour (RF), cassava and ginger starch and their formulated blends.

Sample	WBC (%)	SP (g/g)	S (%)
RF	94.40 ±0.40[a]	10.83 ±0.15[d]	9.47 ± 0.61[e]
CaS	68.57 ±2.11[f]	27.70 ±0.10[a]	11.77±0.55[abc]
GS	64.13 ±2.20[g]	13.17 ± 0.31[c]	12.40 ±1.06[a]
RF:CaS (80:20)	89.27 ±1.91[b]	13.13± 0.42[c]	10.73± 0.61[cde]
RF:CaS (60:40)	84.57 ±1.17[c]	13.33 ±0.68[c]	12.20 ±0.35[ab]
RF:CaS (40:60)	78.03 ±1.00[d]	19.30 ± 3.40[b]	11.67±1.62[abc]
RF:CaS (20:80)	70.47 ±1.60[f]	20.10 ±1.70[b]	7.80 ±0.40[f]
RF:GS (80:20)	85.07 ±0.23[c]	10.57 ± 0.42[d]	9.93 ±0.61[de]
RF:GS (60:40)	82.53 ±2.27[c]	10.77 ±0.32[d]	10.93 ±1.10[bcd]
RF:GS (40:60)	74.00 ±2.43[e]	11.80 ± 0.17[cd]	12.20 ± 0.20[ab]
RF:GS (20:80)	70.00 ±1.60[f]	12.07± 0.32[cd]	12.87± 0.50[a]

RF, CaS, GS are rice flour, cassava starch and ginger starch respectively. Assays were performed in triplicate. Mean ± SD values superscripted by different letters are significantly different from each other (p<0.05). WBC = water binding capacity, SP = swelling power, S = solubility.

significant level.

RESULTS AND DISCUSSION

Color measurement

Most consumers use color as one of the important parameters to evaluate the quality of rice noodles (Asenstorfer et al., 2010; Thomas et al., 2013). According to the results (Table 1), RF and the two native starches selected had a white (lightness) color. However, there was a significant difference in their lightness values with CaS having highest (97.19) whilst the least lightness was recorded for GS (95.35). Both RF and CaS had a red shade whilst GS had a green shade. The two starches under study with the RF had a yellowish color with GS recording a high b* value of (3.61) while CaS having a lower yellowness with b* value (1.71). According to the statistical analysis conducted, all the three samples under study were significantly different (p<0.05) from each other as in L* and a* values. The b* values recorded similar significant difference among the three samples under study. Finally, the overall whiteness among the three samples were significantly different from each other, which would influence the overall color of the formulated blends hence affects the color of the noodles produced. Starches with high value for lightness and low value for chroma are mostly preferred for noodles production (Tan et al., 2009). Hence, CaS will be preferred over GS for noodle processing.

Water binding capacity (%), swelling power (g/g) and solubility (%) of RF, CaS, GS and their formulated blends

Table 2 shows the analysis of water binding capacity (WBC), swelling power (SP) and solubility (S). The water binding capacity analyzed results revealed a significant difference at p<0.05 among all the samples. The rank

Table 3. Pasting properties of Rice flour paste (RF), cassava starch (CaS) and ginger (GS) starch and their formulated blends.

Sample	PV (RVU)	TV (RVU)	RBD (RVU)	FV (RVU)	RSB (RVU)	P_{time} (min)	PT (℃)
RF	192.08 ± 0.69[f]	138.00 ±5.32[f]	28.15 ±3.01[d]	288.83±3.12[b]	52.22 ±1.59[a]	6.87±0.07[ab]	91.55±0.52[a]
CaS	341.50±5.55[a]	140.72±3.73[ef]	58.80 ±0.43[a]	231.36 ±5.58[fg]	39.18 ±0.15[d]	4.15 ± 0.04[g]	70.90 ±0.09[f]
GS	184.08 ±1.01[g]	165.05 ±1.35[b]	10.34 ±0.33[gh]	241.20 ±1.85[e]	31.56 ±1.06[f]	6.34 ±0.12[c]	88.73 ±0.45[b]
RF:CaS (80:20)	227.36 ±1.20[e]	183.92±0.87[a]	19.11 ±0.41[e]	317.78 ±2.51[a]	42.12 ± 0.49[c]	6.78 ±0.10[b]	79.47 ±0.46[c]
RF:CaS (60:40)	232.53 ±2.15[d]	163.89±3.88[b]	29.52 ±1.05[d]	270.03 ±7.77[c]	39.29 ± 0.90[d]	6.04 ±0.08[d]	73.37 ±0.03[d]
RF:CaS (40:60)	254.31 ±3.05[c]	146.86±0.81[d]	42.28±0.58[d]	237.17 ±1.20[ef]	38.04 ±0.29[d]	5.27 ±0.07[e]	72.02 ±0.51[e]
RF:CaS (20:80)	305.30 ± 0.48[b]	145.30±0.87[de]	52.41 ± 0.21[b]	225.61 ±1.00[g]	35.60 ±0.10[e]	4.67 ±0.00[f]	71.73 ±0.06[e]
RF:GS (80:20)	169.78 ±1.73[h]	144.61±4.09[de]	14.83±1.60[f]	262.42±2.57[d]	44.88 ±2.10[b]	6.78 ±0.10[b]	89.20 ±0.00[b]
RF:GS (60:40)	159.86 ±0.10[i]	139.86±1.72[ef]	12.51 ±1.12[fg]	239.22 ±8.07[ef]	41.51 ±2.13[c]	6.36 ±0.10[c]	89.23 ±0.06[b]
RF:GS (40:60)	156.83 ±1.04[i]	145.39±0.98[de]	7.30 ±0.05[h]	215.17 ±2.57[h]	32.42 ±1.27[f]	6.24 ±0.08[c]	89.23 ±0.90[b]
RF:GS (20:80)	158.61 ±0.92[i]	156.08 ±1.05[c]	1.53±0.32[i]	225.36±6.05[g]	30.56±1.40[f]	6.96±0.08[a]	88.45±0.78[b]

All values are means of triplicate determination. Values having different letters within the same column are significantly different from each other (p<0.05). PV = peak viscosity; TV = trough viscosity, RBD = relative breakdown; FV = final viscosity; RSB = relative setback; Ptime = peak time (time from onset of pasting to peak viscosity); PT = pasting temperature (temperature at which peak viscosity was reached); RVU = Rapid Visco-Analyzer units

order for WBC among the three main samples under study was RF>CaS>GS likewise the formulated blends. The difference in the proportion of crystalline and amorphous regions within the granule resulted in these water absorption capacity variations (Kolawole et al., 2013). Thus, less amount of water is absorbed by starch granule with a smaller proportion of weakly bonded amorphous material (Kolawole et al., 2013) hence, GS showed such characteristic.

As reported by Oke et al. (2013), restricted type of swelling starches are desired for the production of noodles since the granule after swelling must remain intact and stable against shearing during thermal processing. The analyzed resulted presented in Table 2 revealed that, there was significant difference at $p<0.05$ among all the samples under study. CaS (27.27 g/g) recorded the highest whilst RF had the least (10.83 g/g). Also, GS had SP of 13.17 g/g. This difference was likewise depicted among their formulated blends with the exception of RF:GS (40:60) and RF:GS (80:20) which had no significant difference from each other. Also, the mean S of all the samples under study had significant differences among them, with GS (12.40%) recording the highest whilst RF (9.47%) recorded the least. The highest S recorded by the GS in this study is attributed to the easy solubility of the linear fraction (amylose) which leach out during swelling process since it is loosely linked with the rest of the macro molecular structure (Soni et al., 1993; Adebowale et al., 2014). The results obtained for SP and S were in the same range of the values reported by Qazi et al., 2014. However, Adebowale et al. (2014) recorded SP and S values for GS as 10.86 g/g and 10.17% respectively which are in contrast with the recorded results in this work which might be due to difference in varieties/cultivars and also the difference in temperature at which it was heated. As pointed out by Kolawole et al. (2013), the SP and S of ginger starch increases with an increased temperature.

Pasting characteristics of rice flour (RF), cassava (CaS) and ginger starch (GS) and their formulated blends

Table 3 highlights the pasting properties of RF, CaS, GS and their formulated blends. From the analytical results, there was significant difference ($p<0.05$) among the samples with all the pasting properties under study. The rank order for PV among the three main samples under study was CaS> RF>GS. There is an increase in viscosity with granule swelling along with amylose leaching, while a decrease of viscosity may be due to further shearing of granule (Sharma et al., 2009; Qazi et al., 2014). With the formulated blends, PV of RF increased as the CaS proportion increased this is confirmed by the results obtained by Qazi et al. (2014). However, the blends of GS showed otherwise that is, as the proportion of GS increased, only RF:GS (80:20) had a significant difference at $p<0.05$ p whilst RF:GS (60:40), (40:60) and (20:80) showed no significant difference from each other. GS recorded a higher TV than RF and CaS. The TV of RF increased with increasing GS and the opposite happened for CaS. The rank for RBD was recorded as CaS>RF>GS. The highest RBD value for the blends formulation was recorded by RF:CaS (20:80) and the least was recorded by RF:GS(20:80) which was as a results of the source of starch. FV and RSB recorded a similar ranking of RF>CaS>GS. The FV values of RF

Table 4. Textural properties of Rice flour paste (RF), cassava starch (CaS) and ginger (GS) starch and their formulated blends.

Sample	Hardness (g)	Adhesiveness	Springiness(mm)	Cohesiveness	Gumminess(g)	Chewiness(g×mm)
RF	101.25 ±7.14^{f}	-69.74±1.50^{g}	0.93±0.01^{b}	0.51 ±0.00^{e}	51.08±3.31^{d}	47.34 ±3.32^{f}
CaS	62.08±3.00^{g}	ND^{a}	1.83±1.22^{a}	0.85 ±0.04^{a}	53.00±5.00^{d}	55.83 ±4.76^{ef}
GS	460.48±9.22^{a}	-20.72^{b}±2.12^{b}	0.85±0.12^{b}	0.23 ±0.02^{h}	81.56±11.25^{a}	91.17 ±8.73^{a}
RF:CaS (80:20)	103.73±1.47^{f}	-31.91±3.99^{bc}	0.93±0.00^{b}	0.60±0.01^{d}	62.44 ± 0.55^{b}	58.10± 0.56^{de}
RF:CaS (60:40)	103.20±1.97^{f}	-10.18±1.32^{b}	0.96 ±0.01^{b}	0.68±0.01^{c}	70.63±0.58^{bc}	66.76± 0.77^{bcd}
RF:CaS (40:60)	90.61±3.03^{f}	ND^{a}	1.01±0.02^{b}	0.73± 0.02^{bc}	65.71 ±3.02^{c}	66.39± 3.86^{bcd}
RF:CaS (20:80)	63.62±2.16^{g}	ND^{a}	1.10±0.20^{b}	0.76 ±0.02^{b}	47.98±2.11^{d}	52.87 ±8.58^{ef}
RF:GS (80:20)	141.92±7.06^{e}	-16.74 ±1.50^{d}	0.94±0.03^{b}	0.46±0.05^{ef}	65.04 ±3.02^{c}	61.23±1.38^{cde}
RF:GS (60:40)	177.61±1.05^{d}	-23.41±5.67^{e}	0.95±0.00^{b}	0.42±0.06^{f}	75.79 ±7.16^{ab}	72.19 ±7.60^{b}
RF:GS (40:60)	238.81±13.15^{c}	-13.23 ±1.22^{cd}	0.85±0.03^{b}	0.32±0.04^{g}	77.15±6.43^{ab}	65.11 ±2.35^{bcd}
RF:GS (20:80)	293.34±21.90^{b}	-7.78±1.63^{b}	0.88±0.04^{b}	0.27±0.01^{h}	78.88 ±5.41^{ab}	69.05 ±2.46^{bc}

Means followed by different letters within the same column are significantly different from each other at P<0.05. Also, ND = not detected. HD = Hardness, AD = adhesiveness, SP = springiness, CO = cohesiveness, GU = gumminess, and CH = chewiness.

reduces as the proportion of CaS increases except that of RF:CaS (80:20) which deviated but falls in agreement with the results by Qazi et al. (2014) who recorded increasing values of FV as the CaS increased. However, though the RSB values for RF was decreased as the proportion of GS got increased, the values recorded were closer to the values recorded for that of RF than that of GS; Qazi et al. (2014) reported similar results. The results recorded in this study may be as a result of the granule size of the starches involved since granule size of the blends plays an important role in the setback (Punchaarnon et al., 2008). Both P_{time} and P_T also recorded a similar ranking of RF>GS>CaS. The difference in P_T among RF, GS and CaS might be as a result of the changes in the interior structure of starches which can occur in both amorphous and crystalline (Katayama et al., 2002; Thao and Noomhorm, 2012). The addition of CaS significantly reduced the pasting temperature of RF which indicates a reduction in the energy requirement during processing of various products with such blends and therefore, makes it better to be considered over GS when there is the need to save energy. When all other properties are equal, starch/flour with lower P_{time} and P_T may be desired more for technical and economic reasons (Iwuoha, 2004; Baah et al., 2009; Oke et al., 2013). However, for thermal, shear and mechanical stability, starches with high P_T will rather be considered since they have a strong bonding forces within the granule interior which provide higher resistance to mechanical agitation, hence, the results of lower PV and SW (Peroni et al., 2006). To determine the industrial application and use of flour/starch in various food products, pasting properties play an important role since they influence the texture, shearing and mechanical stability as well as the digestibility of starchy foods.

Textural properties of RVA gels

As summarized in Table 4, the textural properties of Rice flour (RF), Cassava starch (CaS), ginger (GS) starch and their formulated blends varied significantly. From the results obtained for hardness, GS recorded the highest hardness of (460.48 g) followed by RF (101.25 g) then CaS (62.08 g). The hardness value recorded for GS is related to the presence of strong bonding force within the granule interior as observed for its pasting properties and swelling power (Peroni et al., 2006). Harder gels exhibited by starches tend to have higher amylose content and longer amylopectin chains (Mua and Jackson (1997). Peroni et al. (2006) recorded a higher amylose content value of 26.5% for ginger starch (GS) and a lower amylose content of 19.8% for CaS hence, the high and low hardness as recorded for GS and CaS respectively in this study might be as a result of the variation in their amylose content. Results from Sandhu and Singh (2007), showed that amylose had a positive correlation with hardness (r=0.511, p<0.05) and gumminess (r=0.792, p<0.01) of starch gels. A highly significant correlation was found between high amylose and general acceptability of rice noodles (Bhattacharya et al., 1999). The addition of GS increased the hardness of the RF paste in accordance with the ratio whereas the increment of CaS rather reduced the hardness of RF and the values were more closer to the value obtained for CaS. The adhesiveness of RF and GS were (-69.74 g*s) and (-20.72 g*s) respectively whilst that of CaS, RF:CaS (40:60) and RF:CaS (20:80) were *not detected* this result is not different from the result obtained by Li et al. (2014) as they also did not record any values for adhesiveness of CaS. The adhesiveness recorded for the formulated blends of RF and GS at various ratios had a

Table 5. Storage modulus (G'), loss modulus (G") and tanδ of rice flour paste (RF), cassava starch (CaS) and ginger (GS) starch and their formulated blends at 10.0 Hz.

Sample	G' (Pa)	G"(Pa)	tan (δ)
RF	93.45±1.6[a]	21.89±0.6[c]	0.23±0.01[h]
CaS	33.81±1.4[e]	17.29±0.3[ef]	0.51±0.02[a]
GS	46.94±1.6[d]	21.30±0.6[c]	0.45±0.02[b]
RF:CaS (80:20)	89.59 ±9.3[a]	27.64±2.0[a]	0.31±0.01[e]
RF:CaS (60:40)	67.37±4.8[c]	24.70±1.0[b]	0.37±0.03[d]
RF:CaS (40:60)	68.38±4.1[c]	24.16±0.1[b]	0.35±0.03[d]
RF:CaS (20:80)	53.42±4.4[d]	22.50±0.4[c]	0.42±0.03[c]
RF:GS (80:20)	80.32±7.0[b]	20.76±1.0[c]	0.26±0.01[gh]
RF:GS (60:40)	65.66±3.6[c]	17.60±0.4[ef]	0.27±0.01[fg]
RF:GS (40:60)	54.43±9.2[d]	16.20±1.6[f]	0.30±0.02[ef]
RF:GS (20:80)	50.87±2.7[d]	18.25±0.6[d]	0.36±0.01[d]

Means followed by different letters within the same column are significantly different from each other at P<0.05.

great influence on the adhesiveness of RF since the values recorded were closer to that of GS. In this study, springiness (SPR) is the only parameter which did not record any significant difference at p<0.05 among RF, CaS, GS and their blends. This brings us to the conclusion that the addition of either CaS or GS did not affect the springiness of RF. The cohesiveness ranking was recorded as CaS>RF>GS. The cohesiveness of RF increased with increasing CaS and the values were closer to that recorded for CaS. In contrast, the addition of GS rather reduced the cohesiveness as the proportion of GS increased. Whilst the gumminess of RF was greatly affected by the addition of CaS, the increasing addition of GS did not have a significant effect on RF. There was a significant difference at p<0.05 recorded in the rank RF<CaS<GS for chewiness parameter. The chewiness of RF was greatly affected by the addition of GS whilst the addition of CaS slightly affected the chewiness of RF. Based on the results obtained in this study, it can be concluded that CaS and GS had different textural properties. These variations in the textural properties significantly influenced the textural properties of RF when blended in various proportions and subsequently will affect the final product such as noodle's cooking quality and acceptance since the overall quality of cooked noodles is basically assessed by its texture.

Dynamic rheological properties of RF, CaS, GS and their formulated blends

Table 5 summarizes the G' and G" values at 10.0Hz of RF, the individual starches and the blends at 25°C. As shown by the dynamic moduli (G' and G") values, it was revealed that all the blends exhibited a weak gel behavior due to the positive nature of the slopes and the magnitude of G' (33.81-93.45 Pa) which were much higher than those of G" (16.20-27.64 Pa). From Figures 1 and 3, it can be seen that there is a significant change in the G' results of RF when blended with CaS and GS in the various ratios than the changes in G" respectively. The discrepancies in the granules properties such as rigidity and integrity results in the changes of in their elastic properties (Lu et al., 2008). This phenomenon shows that the elasticity of RF is greatly affected by the addition of these starches at various ratios; similar results were recorded by Sun and Yoo (2011) as they blended rice flour with potato starch. The G' values of RF:CaS (93.45-53.42 Pa) at various ratios were significantly lower than that of RF however, the G"(21.89-27.64 Pa) value of RF saw a slight increase. Also, the dynamic moduli of RF (G'=93.45-50.87 Pa, G"=21.89-16.20 Pa) was constantly reduced by the addition of GS at an increasing ratios (Figure 3). This observed result indicates that these blend samples could have been diluted by individual starches with lower dynamic moduli compared to RF.

All the samples under study were more elastic than viscous since the tan δ (G"/G') values were within the range of 0.23-0.51 (tan<1). The tan δ values of RF blends (0.26-0.42) were much lower than that of the individual starches GS and CaS (0.45 and 0.51 respectively) (Figures 2 and 4). The higher tan δ values recorded by the individual starches in effect raised the tan δ values in their blends with RF thereby reducing the elasticity of RF. However, the tan δ values recorded for RF:GS were smaller (0.26-0.36) as compared to that of RF:CaS (0.31-0.42) blends. In conclusion, even though none of the starches under study could increase the elasticity of RF

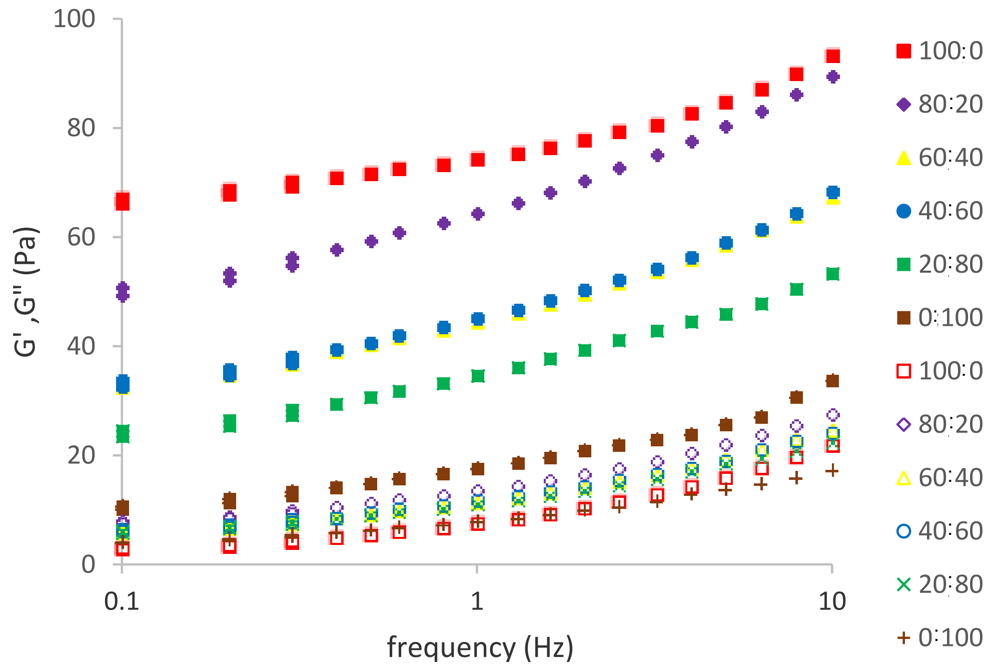

Figure 1. Dynamic mechanical spectra as a function of frequency for RF: CaS blends at 25°C (Closed symbols represent G', open symbols represents G").

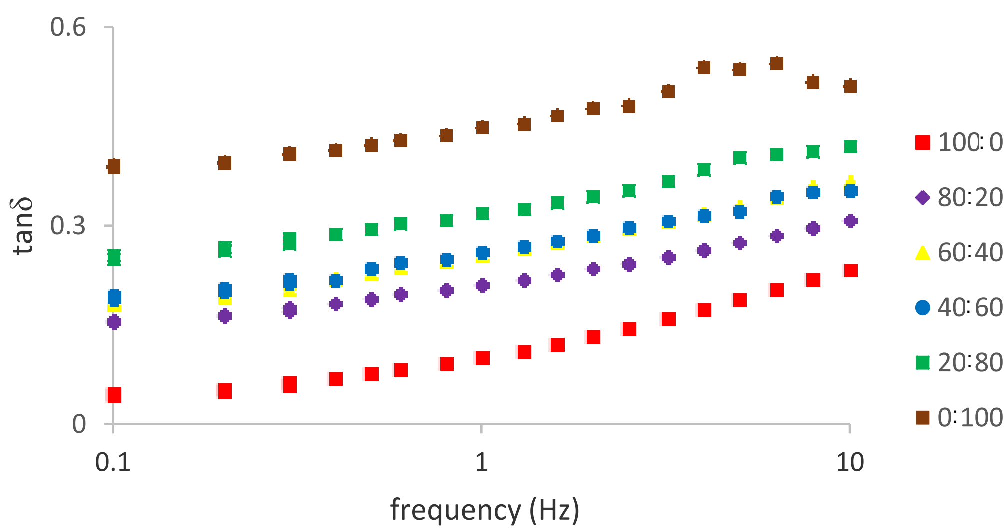

Figure 2. The tan δ as function of frequency for RF: CaS blends at 25°C.

however blends with GS did not have much reduction effect on the elasticity of RF and therefore can be considered over Cas. These softer and weaker gels observed for both CaS, GS and their formulated blends might be as a result of the reduction in leached-out amylose, resulting in a reduction of molecular entanglements for the gel network (Oh et al., 2010).

CONCLUSION AND RECOMMENDATION

In this study, a broad variation of pasting, textural and dynamic rheological properties were observed among RF, CaS, GS and their formulated blends. Under the pasting property, GS exhibited the appropriate characteristics in most of the pasting parameters over

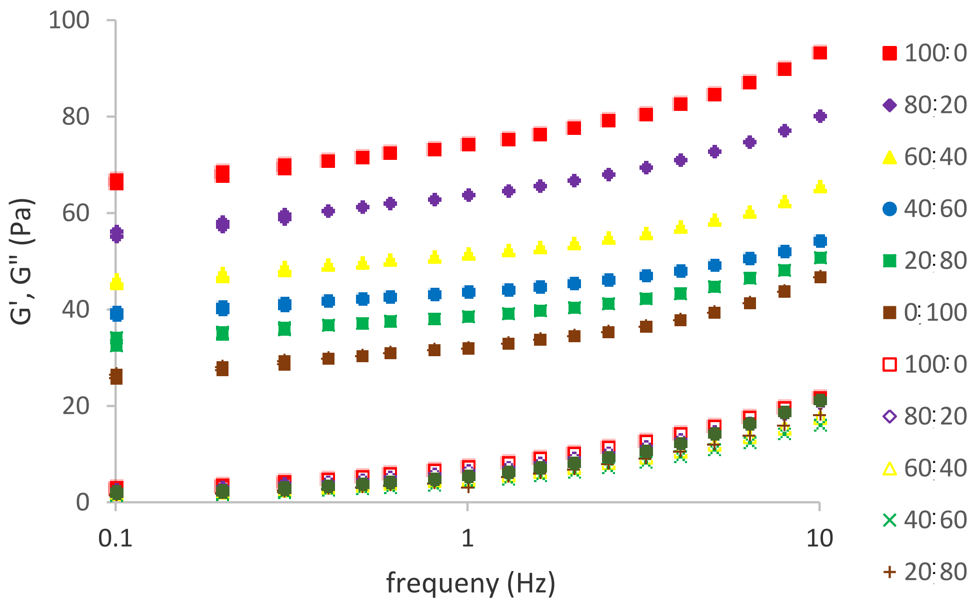

Figure 3. Dynamic mechanical spectra as a function of frequency for RF: GS blends at 25°C (Closed symbols represent G', open symbols represents G").

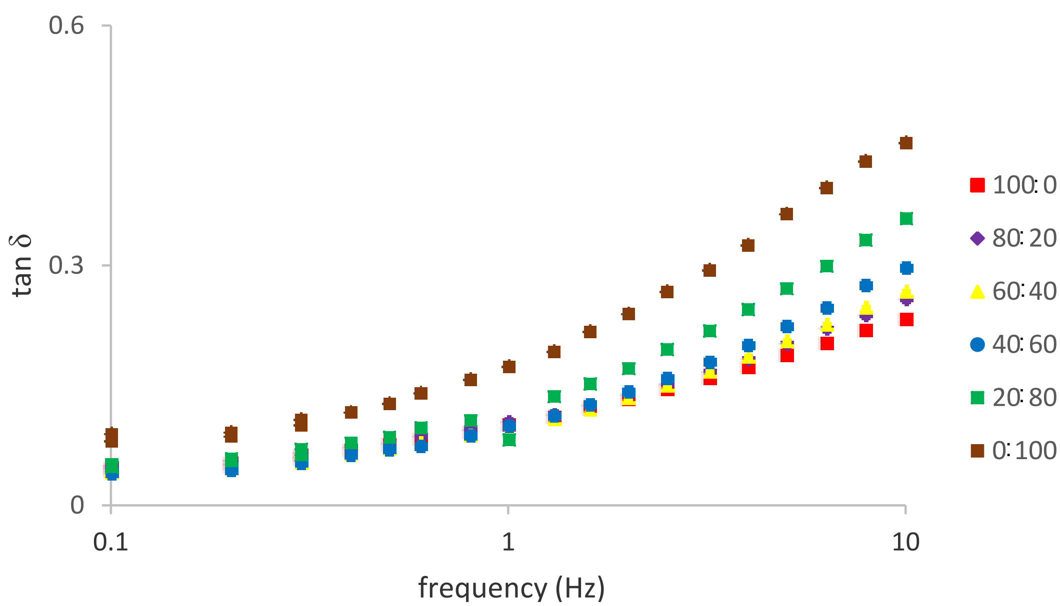

Figure 4. The tanδ as function of frequency for RF: GS blends at 25°C.

CaS such as, GS recorded a higher TV, FV, P_t as well as a slightly lower (PV and RBD) and slightly higher P_T. That is, GS having a higher FV will result in firmness of noodles produced (out) thereby increasing the firmness of RF noodles when blended. Starches with higher TV generally exhibited superior eating quality and lower cooking loss whilst those with higher FV are related to high shear resistance hence, GS exhibiting these characteristics makes it better to be selected over CaS in the blend formulations with RF. However, CaS recording a lower and higher values for P_T and PV respectively makes it better to be considered for reduction in energy requirement during processing. More so, textural properties are major characteristics for assessing the quality of rice noodle. GS recording the higher value of HD which eventually resulted in higher HD in all its blend with RF, makes it better to be selected over CaS. Finally, CaS and GS and their blends with RF all exhibited a weak gel behavior as shown by their dynamic moduli (G' and G") values. Even though, none of these starches under study could increase the elasticity of RF however blends with GS did not have much reduction effect on the elasticity of RF and therefore can be considered over CaS. The results obtained in this study, makes GS fit to be considered in the modification of RF for noodle production. Upon the various characteristics exhibited by native GS in this study, it is recommended that various modification methods be used to improve the properties of GS which will help widen its application scope in the food industry.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

AACC (2000). Approved Methods of the American Association of Cereal Chemists. Saint Paul, MN: American Association of Cereal Chemists.

AACC (2003). Determination of the pasting properties of rice with the rapid visco analyser. Aproved methods of the *American Association of Cereal Chemist* (10th Ed.). Saint Paul, Minnesota, USA

Adebowale BO, Gbenga BL, Yewande F (2014). Morphology, functional and pasting properties of ginger starches prepared by four different drying methods. Br. J. Pharm. Res. 4(12):1439.

Afolayan MO, Adama KK, Oberafo A, Omojola M, Thomas S (2014). Isolation and Characterization Studies of Ginger (Zingiber officinale) Root Starch as a Potential Industrial Biomaterial. Am. J. Mater. Sci. 4(2):97-102.

Asenstorfer RE, Appelbee MJ, Mares DJ (2010). Impact of protein on darkening in yellow alkaline noodles. J. Agric. Food Chem. 58(7):4500-4507.

Baah FD, Maziya-Dixon B, Asiedu R, Oduro I, Ellis W O (2009). Nutritional and biochemical composition of D. alata (Dioscorea spp.) tubers. J. Food Agric. Environ. 7(2): 373-378.

Bhattacharya M, Zee SY, Corke H (1999). Physicochemical properties related to quality of rice noodles. Cereal .Chem*.* 76(6): 861-867.

Daramola B, Osanyinlusi SA (2006). Investigation on modification of cassava starch using active components of ginger roots (Zingiber officinale Roscoe). Afr. J. Biotechnol. 5(10).

Iwuoha CI (2004). Comparative evaluation of physicochemical qualities of flours from steam-processed yam tubers. Food Chem. 85(4):541-551.

Kasemsuwan T, Bailey T, Jane J (1998). Preparation of clear noodles with mixtures of tapioca and high-amylose starches. Carbohydr. Polym. 36(4):301-312.

Katayama K, Komae K, Kohyama K, Kato T, Tamiya S, Komaki K (2002). New sweet potato line having low gelatinization temperature and altered starch structure. *Starch-Stärke*, 54(2): 51-57.

Kaur L, Singh J, Singh N (2005). Effect of glycerol monostearate on the physico-chemical, thermal, rheological and noodle making properties of corn and potato starches. Food Hydrocolloids 19(5): 839-849.

Kolawole SA, Igwemmar NC, Bello HA (2013). Comparison of the physicochemical properties of starch from ginger (*Zingiber officinale*) and maize (*Zea mays*). Int. J. Sci. Res. pp. 2319-7064.

Li S, Zhang Y, Wei Y, Zhang W, Zhang B (2014). Thermal, pasting and gel textural properties of commercial starches from different botanical sources. *J. Bioprocessi. Biotech. 4*(4),1p.

Lu TJ, Duh CS, Lin JH, Chang YH (2008). Effect of granular characteristics on the viscoelastic properties of composites of amylose and waxy starches. Food Hydrocolloid. 22:164-173

Mua JP, Jackson DS (1997). Relationships between functional attributes and molecular structures of amylose and amylopectin fractions from corn starch. *J.Agri. Food Chemi.* 45(10): 3848-3854.

Oh JH, Kim MJ, Yoo B (2010). Dynamic rheological properties of rice flour-starch blends. *Starch‐Stärke, 62*(6): 321-325.

Oke MO, Awonorin SO, Workneh TS (2013). Effect of varieties on physicochemical and pasting characteristics of water yam flours and starches*. African journal of Biotechnology*, 12(11).

Peroni FHG, Rocha TS, Franco CML (2006). Some structural and physicochemical characteristics of tuber and root starches. *Food Sci.Technol. Int.*12(6): 505-513.

Puncha-arnon S, Pathipanawat W, Puttanlek C, Rungsardthong V, Uttapap D (2008). Effects of relative granule size and gelatinization temperature on paste and gel properties of starch blends. *Food Res. Int.*41(5): 552-561.

Qazi IM, Rakshit SK, Tran T, Ullah J, Khan Z (2014). Effect of Blending Selected Tropical Starches on Pasting Properties of Rice Flour. Sarhad J. Agric. 30(3): 357-368.

Sandhu KS, Singh N (2007). Some properties of corn starches II: Physicochemical, gelatinization, retrogradation, pasting and gel textural properties. Food Chem. 101(4):1499-1507.

Sharma R, Oberoi DPS, Sogi DS, Gill BS (2009). Effect of sugar and gums on the pasting properties of cassava starch. J. Food Processing Preserv. 33(3): 401-414.

Soni PL, Sharma H, Dun D, Gharia MM (1993). Physicochemical properties of Quercus leucotrichophora (Oak) starch. *Starch‐Stärke*, 45(4): 127-130.

Sun DS, Yoo B (2011). Rheological and thermal properties of blend systems of rice flour and potato starch. Food Sci. Biotechnol. 20(6):1679-1684.

Surojanametakul V, Tungtakul P, Varanyanond W, Supasri R (2002). Effects of partial replacement of rice flour with various starches on the physicochemical and sensory properties of Sen Lek noodle. Kasetsart J. Nat. Sci. 36: 55-62.

Talele PB, Sharma KS, Dalvi PB, Nandan SS (2015). Isolation of starch from Ginger rhizome (*Zingiber officinale*). J. Pharmacogn. Phytochem. 3(6):157-162.

Tan HZ, Li ZG, Tan B (2009). Starch noodles: History, classification, materials, processing, structure, nutrition, quality evaluating and improving. Food Res. Int. 42(5): 551-576.

Thao HM, Noomhorm A (2012). Physiochemical properties of sweet potato and mung bean starch and their blends for noodle production. J. Food Process.Technol. *2*(1).

Thomas R, Yeoh TK, Wan-Nadiah WA, Bhat R (2014). Quality Evaluation of Flat Rice Noodles (Kway Teow) Prepared from Bario and Basmati Rice. *Sains Malaysiana*, 43(3):339-347.

Yoenyongbuddhagal S, Noomhorm A (2002). Effect of physicochemical properties of high-amylose Thai rice flours on vermicelli quality. Cereal Chem. 79(4):481-485.