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Research article

Combined impact of freezing and soaking times on different cowpea varieties' flour functionality and resultant gel strength, sensory and product yield of moi-moi

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Abstract: The preparation of moi-moi either from cowpea flour (processed by dry-milling) or paste (processed by wet-milling) has evolved from the indigenous processing methods. Feasibly, freezing should enhance the characteristics of the cowpea grain, and when combined with conventional processing, help to improve emergent products. In this current work, therefore, the combined impact of freezing with soaking times on different cowpea varieties' flour functionality and resultant gel strength, sensory and product yield of moi-moi were studied. Analysis of flour functionality involved the determinations of moisture content, bulk density, oil absorption capacity, swelling index and water absorption capacity, whereas those of moi-moi products involved gel strength, sensory and (product) yield. Across the cowpea flour samples, the functional attributes significantly differed ($p < 0.05$). Moi-moi products' gel strength of dry-milled appeared higher than wet-milled by specific variety and soaking times. Moi-moi products' sensory attributes of taste, color, texture and general acceptability resembled ($p > 0.05$), except for the aroma ($p < 0.05$). Moi-moi products' yield varied widely ($p < 0.05$) by different reconstituted water volumes. Overall, combining freezing with conventional processing that involved reconstituted water volumes of cowpea promises an enhanced moi-moi yield.

Keywords: *Vigna unguiculata*; functionality; freezing; gel strength; moi-moi; soaking time

1. Introduction

Globally, cowpea (*Vigna unguiculata* L. Walp.) occupies cultivated land of about 14 million ha, with estimated annual production yield totalling about 6 million metric tons [1]. Across semi-arid tropics of Southern Europe, Africa, Asia, South and Central America and Southern US, cowpea serves as food/forage [2,3]. Specifically, Africa holds about 84% of the globe's overall production of cowpea [1,4]. In West Africa, Nigeria persists to thrive as the largest consumer/producer of cowpea grain [1,3]. More so, cowpea still remains an affordable global protein source, especially for the low income earners. Despite its extensive consumption in Africa, the cowpea appears underutilised, particularly its immature/mature pods/seeds [5], crucially important to livelihood, given its high-quality nutritive value [1]. Conventional processing methods like boiling, fermentation, germination, soaking and drying enables cowpea to provide functional food ingredients by decreasing the presence of undesirable phytochemicals, and optimising its utilisation, which further enhances its acceptability and nutritional quality [5]. Besides being consumed either alone and or in combination dishes, cowpea seeds have continued to attract considerable interest in other forms like extruded products, flour and paste. By processing the cowpea seeds, food products like moi-moi (a steam-gelled cowpea paste), and akara (an oil fried cowpea paste) have emerged [6–8], which continues to thrive across communities in Nigeria, spreading across the West Africa subregion.

Functionality with respect to food ingredient/product refers to any measurable property, which is applicable to the cowpea context, except those nutritional aspects that affect its utilization [6]. When processed into flour, the resultant foaming, gelation, hydration and pasting attributes in cowpea reflect its suitability in food preparation and product development [9]. Over the years, the preparation of moi-moi either from cowpea flour (processed by dry-milling) or paste (processed by wet-milling) has evolved from the indigenous processing methods, which is based on its sustained high protein content and palatability [7,8]. The transformation of cowpeas into a convenient-to-use milled form to make the moi-moi slurry by reconstitution will save lots of time and energy. In this form the addition of water to form the paste eliminates the soaking, decorticating and milling stages for the consumer [6,8]. Making the best of the soaking as well as dehulling processes of the cowpea grains would eventually influence the moi-moi yield and water take up [9]. Despite being considered the less cumbersome, the use of flour production to make moi-moi appears increasingly popular among domestic and commercial producers [8,9]. Further, in making the moi-moi product, the steaming heat helps to curdle the flour and paste to form a steady gel [8]. When moi-moi is processed from steamed cowpea paste phase separation could occur in the product which could affect the product aesthetics and consumer acceptance [8].

Freshly harvested cowpea possesses high moisture content and can be stored in cans or frozen to make them available especially when required in making the moi-moi [8,9]. Short- and long-term storage of cowpea, however, is affected by the grain percentage moisture contents being between 8%–12% [10]. From the storage perspective and applicable to cowpea, freezing represents a preservation practice that involves the crystallization of water, which requires the removal of latent heat [11,12]. Freezing temperatures of about −18 ℃ or below could help maintain the moisture contents of cowpea to such above-mentioned percentages, slow down the chemical changes, arrest the microbial proliferation, and significantly extend the shelf time [13]. Feasibly, freezing might enhance the characteristics of the cowpea grain and subsequent final products like moi-moi. Combining freezing with cowpea's conventional processing should improve the emergent quality of moi-moi products particularly with respect to (cowpea) varieties. In this current work, therefore, the combined impact of freezing and soaking times on different cowpea varieties' flour functionality and resultant gel strength, sensory and product yield of moi-moi were studied. The analysis of flour functionality involved the determinations of moisture content, bulk density, oil absorption capacity, swelling index and water absorption capacity, whereas those of moi-moi samples involved the determinations of gel strength, sensory and product yield.

2. Materials and methods

2.1. Collection of cowpea samples, and laboratory preparation

For the preparation of the moi-moi product, six different varieties of cowpea commercially available in Nigeria were obtained from the Ekeukwu market (5.48537 ºN, 7.03579 ºE) in Owerri, Imo State, Nigeria. Specifically, the six different cowpea varieties were IT97k-461-4, IT89KD-391, Potasko Brown, IT89KD-288, IT97K-82-2 and Potasko White. The local market association helps to authenticate and assure the consumer safety and product viability of cowpea varieties being sold. The equipment and other materials for the laboratory analysis were provided by the Department of Food Science and Technology and Imo State Government of Nigeria-Agricultural Development Programme (Imo-ADP) HQ.

2.2. Processing of cowpea samples to flour and paste

A schematic flow diagram showing the making of flour samples from the frozen and non-frozen cowpea samples is depicted in Figure 1. In order to make the flour samples, the individual collected cowpea varieties were sorted, cleaned and divided into two portions, one portion was frozen for one week, while the others non-freezed. Thereafter, for all, soaking at different time intervals of 1, 2 and 3 h in water were performed, dehulled, oven-dried and dry-milled using attrition milling machine to obtain the cowpea flour. A schematic flow diagram showing the making of paste from the frozen and non-frozen cowpea samples is depicted in Figure 2. To make the paste samples, the individual cowpea varieties were sorted, cleaned divided into two portions, one portion frozen for one week, while the others non-frozen. Thereafter, samples were soaked (different time intervals of 1, 2 and 3 h) in water, dehulled, and wet-milled using attrition milling machine to obtain the cowpea paste samples.

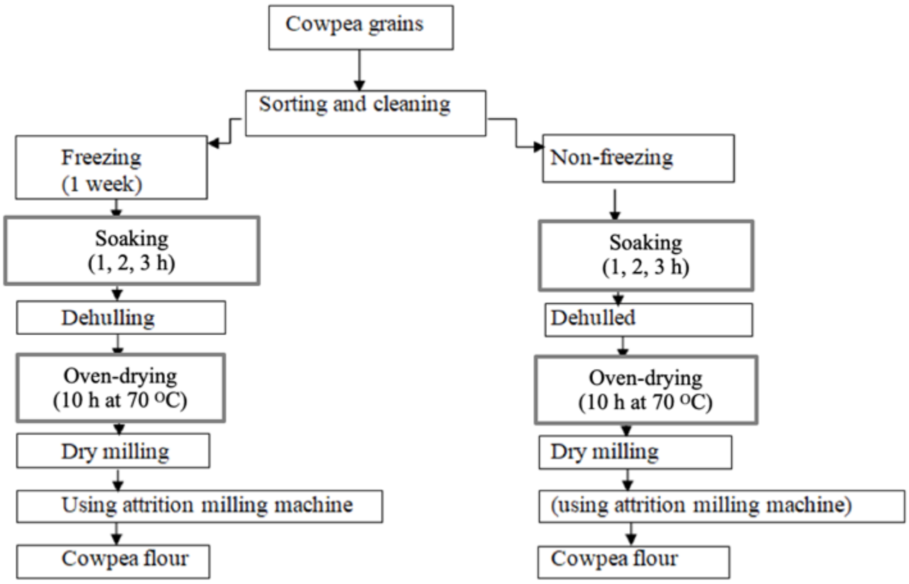

Figure 1. A schematic flow diagram showing the making of flour samples from the frozen and non-frozen cowpea samples.

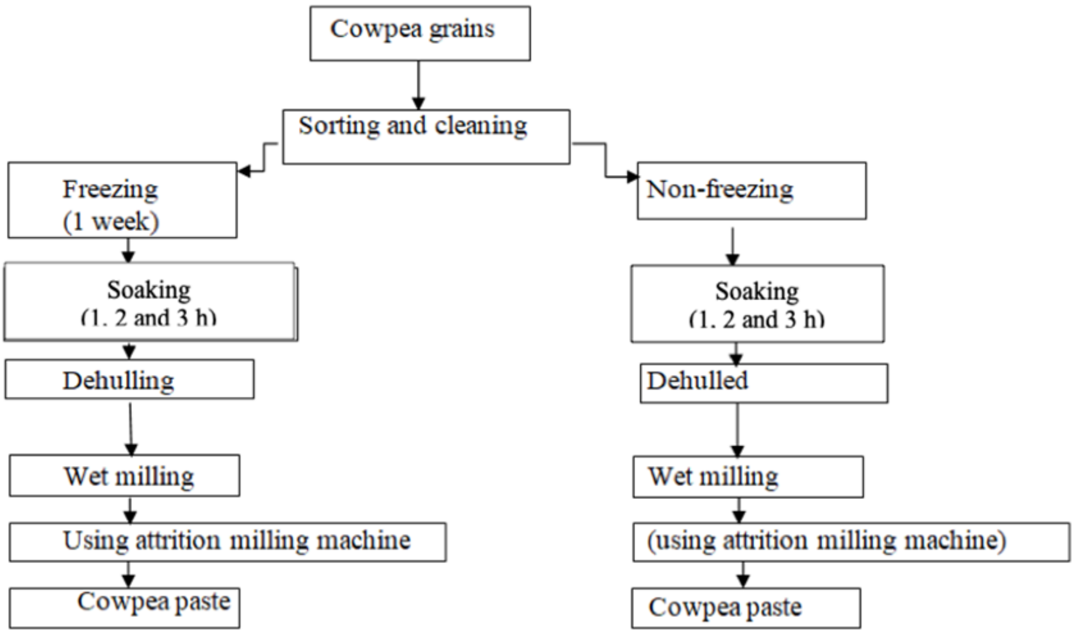

Figure 2. A schematic flow diagram showing the making of paste from the frozen and non-frozen cowpea samples.

2.3. Preparation of sample products (moi-moi) from the cowpea paste

The preparation of moi-moi samples herein followed the method described by Frank-Peterside, Dosumu and Njoku [14] with slight modifications. The fresh cowpea pastes, already prepared from the different cowpea varieties reconstituted with water at (different) volumes (150, 200, 250 and 300 mL), were thoroughly mixed using a blender (HM 430, Selangor, Malaysia) for 5 min, then ingredients were added as prescribed by Frank-Peterside, Dosumu and Njoku[14], then continued mix for about 2 min. To ensure the uniformity of each sample, the same big stainless spoon was used to scoop the cowpea paste into aluminum foil, subsequently wrapped and placed in the pot, with steam holder. All samples were subject to steam cooking of about 40 min, after which the samples were allowed to cool until required for analysis.

2.4. Analytical methods

2.4.1. Flour functionality of different cowpea varieties

Flour functionality of different cowpea varieties from frozen and non-frozen aspects involved determinations of bulk density, moisture content, oil absorption capacity, swelling index, and water absorption capacity.

a). Determination of bulk density

Bulk density (BD) was determined using the method described by Chandi and Sogi [15] with slight modifications. A weighed sample (~10 g) was put in a calibrated 10 mL measuring cylinder. Then the bottom of the cylinder was tapped repeatedly onto a firm pad on a laboratory bench until a constant volume was observed. The packed volume was recorded. The BD was calculated as the ratio of the sample weight to the volume occupied by the sample after tapping.

$$\text{Bulk density (g/mL)} = \text{weight of sample (g)/volume of sample (mL)}. \quad (1)$$

b). Determination of moisture content

Moisture content (MC) was determined using the method described by Association of Official Analytical Chemist[16]. Approximately 5 g of sample will be to be weighed into petri dish of known weight and then dried in the oven at 105 ± 1 °C for ~4 h. The samples will be cooled in a desiccator and re-weighed. The moisture content will be calculated as follows:

$$Percentage\ moisture\ content = \frac{change\ in\ weight}{initial\ weight\ of\ sample\ before\ drying} X100. \quad (2)$$

c). Determination of oil absorption capacity

Oil absorption capacity (OAC) was determined using the method described by Chandi and Sogi [15] with slight modifications. One gram of sample was weighed into a clean conical graduated centrifuge tube and mixed thoroughly with 10 mL oil using a warring mixer for 30 seconds. The sample was then allowed to stand for 30 min at ambient temperature, after which it will be centrifuged at 5000 rpm for 30 min. After centrifugation, the volume of the oil was read directly from the graduated centrifuge tube. The absorbed oil was converted to weight (in grams) by multiplying by the density of oil (0.894 g/mL). The OAC was expressed in grams of oil absorbed per gram (g/g) of flour sample.

$$Absorbed\ oil = Total\ oil - Free\ oil. \quad (3)$$

d). Determination of swelling index

Swelling index (SI) was determined using the method as described by Kaur et al. [17] with slight modifications. This was determined as the ratio of the swollen volume to the ordinary volume of a unit weight of the flour. Approximately 1 g of weighed sample was placed in a clean dry measuring cylinder. Then, the volume occupied was recorded before 50 mL clean water was added. This was left to stand for 1 h, after which the volume was observed and recorded. The swelling index of sample was determined using the equation below:

$$Swelling\ index = \frac{Volume\ occupied\ by\ sample\ after\ swelling}{Volume\ occupied\ by\ sample\ before\ swelling}. \quad (4)$$

e). Determination of water absorption capacity

Water absorption capacity (WAC) was determined using the centrifugation method, modified from Darbour et al. [9]. One gram of sample has been thoroughly mixed with 10 mL distilled water using a warring mixer for 30 s. The sample was then allowed to stand for 30 min at room temperature (30 ± 2 ℃), after which it was centrifuged at 5000 rpm for 30 min. After centrifugation, the volume of the free water (supernatant) was read. The WAC was then calculated as mL of water absorbed per gram of flour.

2.4.2. Gel strength, sensory and yield of moi-moi samples

a). Determination of gel strength

The moi-moi samples already prepared in a cylindrical container, and allowed to cool at room temperature overnight wrapped the moi-moi using aluminum foil, were subject to gel strength (g/mm^2) using the procedure of Kumar and Fotedar [18] with slight modifications. The TX2i texturometer (Stable Micro Systems, Surrey, UK) operated with a cylindrical plunger 10 mm in diameter and cross-head speed of 1 mm/s to a 5 mm depth into the firmly placed (aluminum foil-wrapped) moi-moi, and readings were recorded.

b). Determination of sensory attributes

The sensory evaluation was performed using the method described by Meilgaard et al. [19] with slight modifications. The sensory panelists comprised 25-member semi-trained test panel drawn up from the community of Federal University of Technology Owerri (FUTO). All panelists, already confirmed as consumers of moi-moi, undertook sensory training with evaluation criteria of moi-moi samples. Participation was voluntary, and verbal consent was taken before sensory evaluation. To ensure their privacy, neither names nor gender were reported. The sensory evaluation forms were provided, and each moi-moi treatment were coded. Each panelist had sufficient space, which ensured that one's opinion did not influence the other during the sensory evaluation for aroma, colour, taste, texture and general acceptance, which involved a 9-point hedonic scale where 9: like extremely, 8: like very much, 7: like moderately, 6: like slightly, 5: neither like nor dislike, 4: dislike slightly, 3: dislike moderately, 2: dislike very much, and 1: dislike extremely. Consistent with Çakmakçı et al. [20], each sensory panelist was provided clean warm water to cleanse taste palates between samples, which ensured that the evaluation of previous moi-moi sample did not influence the new one.

c). Determination of the yield

The moi-moi yield was evaluated by comparing the measured weight of cowpea flours against that of moi-moi per sample by percentage. This was calculated as follows:

$$\%Yield = \frac{Mass\ of\ each\ cowpea\ flour\ sample}{Mass\ of\ the\ final\ product\ from\ each\ flour\ sample} X100. \quad (5)$$

2.5. Statistical analysis

One-way analysis of variance (ANOVA) was applied to data obtained from triplicate measurements, and presented as mean ± standard deviation (SD). The probability level was set at $p < 0.05$. Mean differences were resolved using Fischer's least significant difference (LSD). Minitab version 16 (Minitab Ltd., Coventry CV3 2TE, UK) was used to run the data.he heading levels should not be more than 4 levels.

3. Results and discussion

3.1. Effects on flour functionality of different cowpea varieties

Functional attributes (namely MC, SI, WAC, OAC and BD) of flour samples across different cowpea varieties are shown in Table 1. Across the cowpea flour samples, significant differences ($p < 0.05$) were found with such ranges as between 7.11 ± 0.02 and 13.82 ± 0.04 % for MC, 1.21 ± 0.11 and 1.57 ± 0.18 g/mL for SI, 1.90 ± 0.04 and 2.81 ± 0.02 g/g for WAC, 1.23 ± 0.05 and 2.29 ± 0.01 g/g for OAC, 0.38 ± 0.02 and 0.93 ± 0.07 g/mL for BD. On one hand, the peak MC (13.82 ± 0.04%), SI (1.57 ± 0.18 g/mL), WAC (2.81 ± 0.02 g/g), OAC (2.29 ± 0.01 g/g), and BD (0.93 ± 0.07 g/mL) were found in samples E_{NF}, A_F, D_{NF}, F_{NF} and A_F, respectively. On the other hand, the least MC (5.38 ± 0.02%), SI (1.21 ± 0.11 g/mL), WAC (1.90 ± 0.04 g/g), OAC (1.23 ± 0.05 g/g) and BD (0.38 ± 0.02 g/mL) were found in samples F_F, F_{NF}, E_F and E_{NF} (OAC and BD), respectively. Competitive to the current study, De Angelis et al. [21] reported BD of 0.91 g/mL and WAC of 1.01 g/g of refined cowpea flour produced in Benin Republique. These workers understood that such physicochemical attributes as BD (and WAC) would strongly influence the overall food product.

Probably, the differences in WAC and OAC might be owed to the varying compositions of cowpea varieties used in this current study. The quantities of starch present might be responsible for the variations in WAC and SI, whereas the fibre might lower these properties [22]. The freezed cowpea grains obtained significantly reduced MC ($p < 0.05$) over the non-freezed samples, but not so for SI, WAC, OAC and BD at this current study. Besides, WAC would directly influence the ability of some molecules like polysaccharides and proteins to bind moisture/water [21]. In food processing, the properties of ice, water and vapour during freezing occur in phases and transitions. The formed ice during freezing changes how water molecules align, and result in dehydration and solute concentration [23]. It is plausible that the BD of moi-moi of this current study might have been influenced by the density and particle size of the flour, both of which crucial would be in ascertaining the handling ability of the cowpea material [24]. The swelling of food materials would associate with the structural framework of the protein and starch molecules [25].

However, freezing of the cowpea grains samples seemed not to have actually impacted the SI of the flours specific to this current work. Given that environmental impact might strongly influence functional attributes of cowpea varieties, the current findings could be considered preliminary and thus, further investigations is needful.

Table 1. Functional attributes (moisture content, swelling index, water and oil absorption capacity and bulk density) of flour samples across different cowpea varieties.

Sample	Moisture content (%)	Swelling index (g/ml)	Water absorption capacity (g/g)	Oil absorption capacity (g/g)	Bulk density (g/ml)
A_F	$9.44^{f} \pm 0.33$	$1.57^{a} \pm 0.18$	$2.32^{c} \pm 0.10$	$1.82^{bc} \pm 0.17$	$0.93^{a} \pm 0.07$
A_{NF}	$11.57^{c} \pm 0.21$	$1.39^{bcde} \pm 0.17$	$2.08^{ef} \pm 0.02$	$1.66^{de} \pm 0.06$	$0.56^{d} \pm 0.08$
B_F	$10.92^{e} \pm 0.03$	$1.33^{def} \pm 0.01$	$2.17^{de} \pm 0.04$	$1.63^{e} \pm 0.03$	$0.64^{c} \pm 0.01$
B_{NF}	$11.23^{d} \pm 0.01$	$1.30^{def} \pm 0.02$	$1.99^{gh} \pm 0.02$	$1.93^{b} \pm 0.03$	$0.68^{bc} \pm 0.02$
C_F	$7.11^{i} \pm 0.02$	$1.28^{ef} \pm 0.03$	$1.91^{hi} \pm 0.02$	$1.48^{f} \pm 0.05$	$0.74^{b} \pm 0.03$
C_{NF}	$9.21^{g} \pm 0.04$	$1.43^{abcd} \pm 0.05$	$2.19^{d} \pm 0.08$	$1.74^{cd} \pm 0.02$	$0.62^{cd} \pm 0.03$
D_F	$7.55^{h} \pm 0.04$	$1.50^{ab} \pm 0.01$	$2.42^{b} \pm 0.05$	$1.71^{cde} \pm 0.11$	$0.67^{bc} \pm 0.03$
D_{NF}	$11.90^{b} \pm 0.09$	$1.35^{cdef} \pm 0.06$	$2.81^{a} \pm 0.02$	$1.49^{f} \pm 0.04$	$0.40^{e} \pm 0.04$
E_F	$11.45^{cd} \pm 0.06$	$1.41^{bcde} \pm 0.05$	$1.90^{i} \pm 0.04$	$1.47^{f} \pm 0.04$	$0.65^{c} \pm 0.07$
E_{NF}	$13.82^{a} \pm 0.04$	$1.42^{bcd} \pm 0.08$	$2.00^{fg} \pm 0.02$	$1.23^{g} \pm 0.05$	$0.38^{e} \pm 0.02$
F_F	$5.38^{j} \pm 0.02$	$1.48^{abc} \pm 0.03$	$2.33^{c} \pm 0.03$	$2.19^{a} \pm 0.02$	$0.70^{bc} \pm 0.11$
F_{NF}	$7.27^{i} \pm 0.03$	$1.21^{f} \pm 0.11$	$2.28^{c} \pm 0.08$	$2.29^{a} \pm 0.01$	$0.70^{bc} \pm 0.02$
LSD	0.12	0.09	0.05	0.07	0.05

Note: Means with the same superscript do not differ significantly at $p > 0.05$, means with a different superscript are significantly different at $p < 0.05$. $_F$: frozen cowpea grain samples, $_{NF}$: non frozen cowpea samples. A: IT97k-461-4, B: IT89KD-391, C: Potasko Brown, D: IT89KD-288, E: IT97K-82-2, F: Potasko White.

3.2. *Effects on gel strength of different moi-moi products*

Gel strength of moi-moi samples prepared from wet-milled and dry-milled cowpea grains soaked at different time intervals are respectively shown in Tables 2 and 3. Regards the wet milled, there were gel strength ranges at 1 h (from 123.27 ± 1.10 to 174.17 ± 1.33 g/mm^2), 2 h (from 143.87 ± 1.44 to 197.70 ± 2.25 g/mm^2) and 3 h(from 165.37 ± 1.50 to 243.93 ± 5.48 g/mm^2) soaking times. Regards the dry milled, there were gel strength ranges at 1h (from 169.73 ± 0.46 to 242.60 ± 2.25 g/mm^2), 2 h (from 191.73± 1.44 to 294.03 ± 1.67 g/mm^2) and 3 h (from 210.97 ± 0.64 to 344.97± 4.97 g/mm^2) soaking times. Abu et al. [26] understood that swelling related characteristics to be starch-related. These workers also understood SI to strongly and positively correlate with the gel strength in cowpea flours and pastes. Starch degradation in cowpea flours and pastes could inhibit the granule’s ability to trap water and swell during gelatinization.

Comparing Tables 2 and 3, the peak and least gel strength values of dry-milled varied considerably compared to those of wet-milled ones at each specific variety and soaking times. The gel strength of moi-moi samples to increase with soaking time might be because of moisture uptake via polysaccharides (mostly starch) and protein in the flour. Moreover, the protein content of cowpea flour may contribute to the reduced viscosity [21] of this current work, which might reflect the differences in gel strength of the moi-moi samples. Graph trend plot of overall mean gel-strength of samples based on different soaking time intervals is shown in Figure 3. An increased gel strength appears somewhat more in the moi-moi products obtained from freezed compared to non-freezed cowpea grains. Regardless of dry and wet milled methods, the gel strength of moi-moi samples significantly changed ($p < 0.05$), somewhat more across soaking times, and less across the varieties (Tables 2 and 3). Generally, the gels are viscoelastic in nature and usually formed by the interactions of polysaccharides and proteins within food matrix [27]. Indeed, texture is governed by way the structure of water is manipulated by as well as affects the structure of other ingredients contained in the food matrix, and this is so in foods with high water content [28].

Table 2. Gel strength of moi-moi samples prepared from wet-milled cowpea grains soaked at different time intervals.

Samples	Gel strength (penetration rate) of moi-moi by varying soaking times (g/mm^2)		
	1 h	2 h	3 h
A_F	$173.70^{aA} \pm 1.04$	$194.00^{aB} \pm 12.12$	$243.93^{aC} \pm 5.48$
A_{NF}	$172.10^{aA} \pm 1.91$	$197.70^{aB} \pm 2.25$	$216.43^{bC} \pm 5.14$
B_F	$169.03^{bA} \pm 1.44$	$193.63^{aB} \pm 1.10$	$210.23^{cC} \pm 0.98$
B_{NF}	$172.20^{aA} \pm 2.25$	$187.00^{bB} \pm 0.00$	$200.13^{dC} \pm 0.46$
C_F	$171.77^{aA} \pm 1.96$	$185.70^{bB} \pm 1.21$	$196.80^{deC} \pm 0.87$
C_{NF}	$174.17^{aA} \pm 1.33$	$183.07^{bB} \pm 0.29$	$195.00^{eC} \pm 1.04$
D_F	$142.13^{cA} \pm 0.98$	$164.17^{cB} \pm 0.92$	$189.17^{fC} \pm 0.81$
D_{NF}	$132.67^{eA} \pm 1.44$	$160.34^{cdB} \pm 1.67$	$179.40^{gC} \pm 1.39$
E_F	$130.43^{eA} \pm 0.98$	$155.97^{deB} \pm 1.67$	$176.90^{gC} \pm 1.91$
E_{NF}	$135.57^{dA} \pm 0.98$	$152.30^{efB} \pm 2.42$	$171.97^{hC} \pm 0.06$
F_F	$123.27^{gA} \pm 1.10$	$149.50^{fgB} \pm 0.52$	$168.97^{hiC} \pm 0.12$
F_{NF}	$127.34^{fA} \pm 1.10$	$143.87^{gB} \pm 1.44$	$165.37^{iC} \pm 150$
LSD	1.439	3.759	2.380

Note: Means with the same superscript do not differ significantly at $p > 0.05$, means with a different superscript are significantly different at $p < 0.05$. $_F$: frozen cowpea grain samples, $_{NF}$: non frozen cowpea samples. A: IT97k-461-4, B: IT89KD-391, C: Potasko Brown, D: IT89KD-288, E: IT97K-82-2, F: Potasko White.

Table 3. Gel strength of moi-moi samples prepared from dry-milled cowpea grains soaked at different time intervals.

Samples	Gel strength (penetration rate) of moi-moi at different soaking time (g/mm^2)		
	1 h	2 h	3 h
A_F	$242.60^{aA} \pm 2.25$	$294.03^{aB} \pm 1.67$	$344.97^{aC} \pm 4.97$
A_{NF}	$237.63^{bA} \pm 2.37$	$286.80^{bB} \pm 1.21$	$327.77^{bC} \pm 5.14$
B_F	$215.93^{dA} \pm 3.35$	$259.90^{cB} \pm 2.25$	$291.80^{dC} \pm 4.85$
B_{NF}	$216.27^{dA} \pm 1.10$	$242.73^{deB} \pm 3.93$	$264.73^{fgC} \pm 8.37$
C_F	$221.20^{cA} \pm 2.42$	$263.40^{cB} \pm 1.73$	$299.30^{cC} \pm 1.21$
C_{NF}	$207.63^{eA} \pm 2.54$	$244.67^{dA} \pm 2.89$	$280.00^{eA} \pm 5.72$
D_F	$199.50^{fA} \pm 0.87$	$239.40^{eB} \pm 2.77$	$271.80^{fC} \pm 2.25$
D_{NF}	$197.40^{fA} \pm 2.60$	$234.00^{fB} \pm 5.02$	$263.47^{gC} \pm 6.00$
E_F	$190.70^{gA} \pm 4.16$	$229.27^{fB} \pm 1.96$	$259.17^{gC} \pm 2.14$
E_{NF}	$187.07^{gA} \pm 0.06$	$222.67^{gB} \pm 3.18$	$240.00^{hC} \pm 0.87$
F_F	$174.70^{hA} \pm 1.04$	$205.27^{hB} \pm 4.21$	$228.63^{iC} \pm 2.66$
F_{NF}	$169.73^{iA} \pm 0.46$	$191.73^{iB} \pm 1.44$	$210.97^{jC} \pm 0.64$
LSD	2.264	2.927	4.404

Note: Means with the same superscript do not differ significantly at $p > 0.05$, means with a different superscript are significantly different at $p < 0.05$. $_F$: frozen cowpea grain samples, $_{NF}$: non frozen cowpea samples. A: IT97k-461-4, B: IT89KD-391, C: Potasko Brown, D: IT89KD-288, E: IT97K-82-2, F: Potasko White.

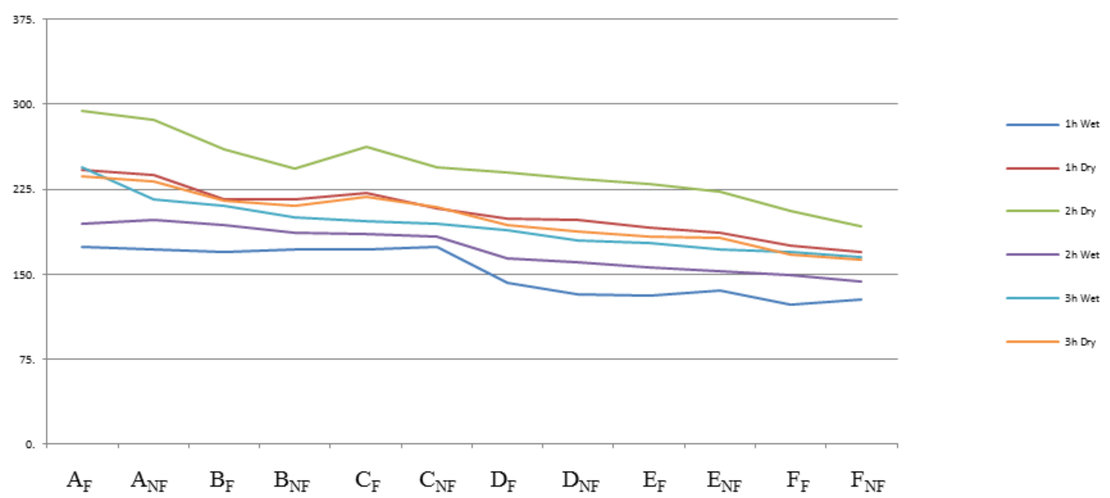

Figure 3. Graph trend plot of the overall mean gel-strength of moi-moi product samples specific different soaking time intervals.

Note: $_F$: frozen cowpea grain samples, $_{NF}$: non frozen cowpea samples. A: IT97k-461-4, B: IT89KD-391, C: Potasko Brown, D: IT89KD-288, E: IT97K-82-2, F: Potasko White.

3.3. *Effects on sensory attributes of different moi-moi products*

The sensory attributes namely, taste, aroma, colour, texture and general appearance of the moi-moi products from different cowpea varieties are shown in Table 4. Across the varieties, the sensory attributes obtained diverse ranges specific to taste (from 6.40 ± 1.55 to 6.77 ± 1.38), aroma (from 6.07 ± 1.14 to 6.80 ± 1.13), colour (from 6.03 ± 1.85 to 6.80 ± 1.50), texture (from 6.60 ± 1.43 to 6.90 ± 1.40), and general appearance (from 6.70 ± 1.54 to 7.13 ± 1.25). Despite these ranges, the sensory attributes of moi-moi product from different cowpea varieties resembled ($p > 0.05$), with the exception of aroma ($p < 0.05$). On one hand, peak values occurred in sensory attributes of taste at B_F (6.77 ± 1.38) approximately equal to C_F (6.77 ± 0.94), aroma at F_F (6.80 ± 1.13), color at F_{NF} (6.80 ± 1.50), texture at C_{NF} (6.93 ± 1.41) and general acceptance at D_{NF} (7.13 ± 1.25). On the other hand, the least values occurred in the sensory attributes of taste at A_{NF}(6.40 ± 1.55), aroma at C_F (6.07 ± 1.14), color at B_F (6.03 ± 1.85), texture at A_{NF} = B_F = F_{NF} (6.60 ± 1.43) and general acceptability at E_F = F_{NF} (6.70 ± 1.54). In the author's opinion, the fact that texture attributes remained unchanged according to the panellists suggests the promising consistency of the moi-moi product at this study. Besides, Nyambaka and Ryley [29] understood that textural damage in food products would depend on such factors like its composition, moisture, pH, as well as product history, e.g., sample dimensions and maturity. Additionally, Okwunodulu, Peter and Okwunodulu [30] reported that the moi-moi from cowpea has been associated with desirable beany flavour. Potentially, the differences in sensory attributes of the moi-moi products detected by the panelists of this study might also be attributed to the cowpea varieties.

Table 4. Sensory attributes of taste, aroma, colour, texture and general appearance in the moi-moi products from different cowpea varieties.

Samples	Different sensory attributes in the moi-moi products				
	Taste	Aroma	Colour	Texture	General acceptance
A_F	$6.57^a \pm 1.14$	$6.47^{ab} \pm 1.22$	$6.73^a \pm 1.29$	$6.80^a \pm 1.42$	$7.00^a \pm 1.37$
A_{NF}	$6.40^a \pm 1.55$	$6.50^{ab} \pm 1.08$	$6.27^a \pm 1.66$	$6.60^a \pm 1.43$	$6.80^a \pm 1.35$
B_F	$6.77^a \pm 1.38$	$6.53^{ab} \pm 1.14$	$6.03^a \pm 1.85$	$6.60^a \pm 1.43$	$6.87^a \pm 1.61$
B_{NF}	$6.67^a \pm 1.21$	$6.40^{ab} \pm 1.33$	$6.30^a \pm 1.80$	$6.90^a \pm 1.40$	$7.00^a \pm 1.20$
C_F	$6.77^a \pm 0.94$	$6.07^b \pm 1.14$	$6.57^a \pm 1.61$	$6.83^a \pm 1.51$	$7.10^a \pm 1.47$
C_{NF}	$6.60^a \pm 1.48$	$6.33^{ab} \pm 1.32$	$6.40^a \pm 1.33$	$6.93^a \pm 1.41$	$7.00^a \pm 1.39$
D_F	$6.73^a \pm 1.57$	$6.57^{ab} \pm 1.41$	$6.33^a \pm 1.52$	$6.90^a \pm 1.32$	$6.93^a \pm 1.41$
D_{NF}	$6.43^a \pm 1.38$	$6.57^{ab} \pm 1.17$	$6.13^a \pm 1.70$	$6.73^a \pm 1.48$	$7.13^a \pm 1.25$
E_F	$6.50^a \pm 1.36$	$6.40^{ab} \pm 1.13$	$6.43^a \pm 1.36$	$6.77^a \pm 1.43$	$6.70^a \pm 1.54$
E_{NF}	$6.53^a \pm 0.97$	$6.47^{ab} \pm 1.11$	$6.40^a \pm 1.83$	$6.67^a \pm 1.42$	$7.00^a \pm 1.14$
F_F	$6.50^a \pm 1.68$	$6.80^a \pm 1.13$	$6.47^a \pm 1.78$	$6.67^a \pm 1.40$	$6.77^a \pm 1.46$
F_{NF}	$6.63^a \pm 1.25$	$6.47^{ab} \pm 1.36$	$6.80^a \pm 1.50$	$6.60^a \pm 1.43$	$6.70^a \pm 1.54$
LSD	N.S.	1.20	N.S.	N.S.	N.S.

Note: Means with the same superscript do not differ significantly at $p > 0.05$, means with a different superscript are significantly different at $p < 0.05$. $_F$: frozen cowpea grain samples, $_{NF}$: non frozen cowpea samples. A: IT97k-461-4, B: IT89KD-391, C: Potasko Brown, D: IT89KD-288, E: IT97K-82-2, F: Potasko White.

3.4. *Effects on yield attributes of different moi-moi products*

Moi-moi products' yield (%) obtained from cowpea varieties reconstituted at different water volumes are shown in Table 5. Clearly, moi-moi products' yield were significantly influenced ($p < 0.05$) by cowpea varieties and reconstituted water volumes. Additionally, the moi-moi products' yield obtained a wide range, that is, 150 mL (from 38.58 ± 1.32 to 60.90 ± 0.68%), 200 mL (from 41.56 ± 2.67 to 62.07 ± 1.53%), 250 mL (from 53.61 ± 2.46 to 65.30 ± 0.52%) and 300 mL (from 55.70 ± 0.89 to 72.04 ± 1.66%). On one hand, the peak moi-moi yield were at B_F (60.90 ± 0.68%) and (62.07 ± 1.53%) for 150 mL and 200 mL respectively, F_{NF} (65.30 ± 0.52%) for 250 mL, and F_F (72.04 ± 1.66%) for 300 mL. On the other hand, the least moi-moi yield were at A_{NF} (41.85 ± 0.27%) for 150 mL and (53.61 ± 2.46%) for 250 mL, A_F (41.56 ± 2.67%) for 200 mL, and C_{NF} (55.70 ± 0.89%) for 300 mL. Further, the moi-moi yield significantly increased ($p < 0.05$) with reconstituted water volumes, except at samples A_F, D_{NF} and E_F that non-significantly decreased ($p > 0.05$) between 150 and 200 mL. Possibly, the increases in MC might add to the bulk/weight of moi-moi product. Reconstituting water volumes particularly between 200 and 250 mL would dramatically increase the moi-moi yield, noticeable at samples A_F (between 41.56 ± 2.67 and 54.85 ± 1.96 %), A_{NF} (between 42.83 ± 0.49 and 53.61 ± 2.46%), D_F (between 47.05 ±0.08 and 62.48 ± 2.15%), D_{NF} (between 45.72 ± 0.53 and 60.45 ± 0.79%), E_F (between 43.97 ± 1.68 and 62.88 ± 1.46%), E_{NF} (between 44.28 ± 0.64 and 59.47 ± 0.92%), F_F(between 45.18 ± 0.36 and 62.31 ± 0.03 %), as well as F_{NF} (between 42.39 ± 0.67 and 65.30 ± 0.52%). Possibly, the cowpea varieties might also be contributing to the moi-moi yield at this study.

Table 5. Moi-moi products' yield (%) obtained from cowpea varieties reconstituted at different water volumes.

Samples	Moi-moi products' yield (%) obtained at different water volumes			
	150 mL	200 mL	250 mL	300 mL
A_F	42.32^{fA} ± 0.59	41.56^{gA} ± 2.67	54.85^{efB} ± 1.96	62.61^{eC} ± 0.72
A_{NF}	41.85^{fA} ± 0.27	42.83^{fgA} ± 0.49	53.61^{fB} ± 2.46	61.47^{eC} ± 2.13
B_F	60.90^{aA} ± 0.68	62.07^{aA} ± 1.53	62.88^{bA} ± 0.23	66.21^{dA} ± 0.96
B_{NF}	56.81^{bA} ± 1.03	57.74^{bA} ± 0.45	62.16^{bcB} ± 1.29	62.56^{eB} ± 0.72
C_F	50.05^{cA} ± 0.91	51.73^{cA} ± 1.03	55.90^{eB} ± 0.35	58.23^{fC} ± 0.12
C_{NF}	48.79^{cA} ± 0.54	50.85^{cB} ± 0.55	54.46^{efC} ± 0.70	55.70^{gC} ± 0.89
D_F	45.78^{dA} ± 0.12	47.05^{dB} ±0.08	62.48^{bcC} ± 2.15	68.99^{bcD} ± 0.77
D_{NF}	45.97^{dA} ± 0.06	45.72^{deA} ± 0.53	60.45^{cdB} ± 0.79	67.56^{cdC} ± 1.16
E_F	44.71^{deA} ± 0.84	43.97^{efA} ± 1.68	62.88^{bB} ± 1.46	66.23^{dB} ± 0.75
E_{NF}	42.42^{fA} ± 1.24	44.28^{efB} ± 0.64	59.47^{dC} ± 0.92	70.08^{bD} ± 0.56
F_F	43.22^{efA} ± 3.27	45.18^{eA} ± 0.36	62.31^{bcB} ± 0.03	72.04^{aC} ± 1.66
F_{NF}	38.58^{gA} ± 1.32	42.39^{fgB} ± 0.67	65.30^{aC} ± 0.52	68.91^{bcD} ± 0.15
LSD	1.22	1.13	1.31	1.04

Note: Means with the same superscript do not differ significantly at $p > 0.05$, means with a different superscript are significantly different at $p < 0.05$. $_F$: frozen cowpea grain samples, $_{NF}$: non frozen cowpea samples. A: IT97k-461-4, B: IT89KD-391, C: Potasko Brown, D: IT89KD-288, E: IT97K-82-2, F: Potasko White.

4. Conclusions

For emphasis, this current work's hypothesis proposed that combining freezing with conventional processing should be a promising approach to improving the cowpea product. To test this hypothesis, the combined impact of freezing and soaking times on different cowpea varieties' flour functionality and resultant gel strength, sensory, and yield of moi-moi products was implemented. Results showed freezed cowpea obtained significantly reduced MC over the non-freezed samples. However, this would not be so for the SI, WAC, OAC and BD. Regardless of dry and wet milling processing, the gel strength of moi-moi samples significantly changed more across soaking times but less across the varieties. Sensory attributes of taste, color, texture and general acceptability resembled, except the aroma. Clearly, the moi-moi products' yield significantly differed across cowpea varieties and reconstituted water volumes. Overall, this current work has demonstrated the combination of freezing with cowpea's conventional processing involving reconstituted water volumes could benefit moi-moi producers in achieving optimal yield. The direction of future work should be to subject the moi-moi products herein to shelf-life tests under different storage conditions, including physicochemical, and microbiological quality.

Ethical guidelines

Participation of the sensory evaluation of this study was voluntary, and the verbal consent was taken from panellists. Additionally, to ensure their privacy, neither their names nor gender were indicated at this study.

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Conflict of interest

The authors have no conflict of interest to declare.

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