

Pasting and Functional Properties of *Monodora Myristica* (Gaertn.) Seed Flour as Affected by Thermal Processing

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ABSTRACT

Monodora myristica (Gaertn.) Dunal is a valuable but underused tropical tree of the Annonaceae or custard apple family. *Monodora myristica* seeds were dehulled, thermally processed by roasting (10, 20, 30min) and boiling (10, 20, 30min), milled into flour and defatted. Raw (control) *Monodora myristica* seeds were dehulled, milled into flour, and defatted without any thermal processing. The effects of thermal processing on the functional and pasting properties of flour samples were investigated. Thermal processing had no significant ($P \geq 0.05$) effect on the water absorption capacity and swelling power of flour samples. Processing had no significant ($P \geq 0.05$) effect on the bulk density of *Monodora myristica* seed flour samples. Flours processed by boiling exhibited significantly higher ($P \leq 0.05$) oil absorption capacity and solubility than the roasted samples. Processing (roasting) did not significantly ($P \geq 0.05$) affect the emulsion capacity of flour samples. The roasted flour sample (RO30) had significantly higher ($P \leq 0.05$) peak, trough, setback, and final viscosity value among processed flours. Roasted samples had a significantly ($P \leq 0.05$) higher breakdown viscosity value than the boiled samples. Thermal processing had no significant ($P \geq 0.05$) influence on the peak time of *Monodora myristica* seed flour. Flour samples from boiled seeds would withstand heating and shear stress compared to other processed samples because of their low breakdown viscosity value. On the other hand, flour from roasted seeds had the highest setback viscosity and would withstand breakdown better than others. Boiled and roasted seed flours of *Monodora myristica* would be useful in the pasta, noodle, and bakery industries.

Keywords: *Monodora myristica*; pasting properties; thermal processing, functional properties.

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I. INTRODUCTION

Monodora myristica (Gaertn.) Dunal is a useful but underutilized tropical tree of the Annonaceae or custard apple family of flowering plants [1], [2]. Different names of *Monodora myristica* in different localities as disclosed by [3]–[5] are: *Iwor* (Itsekiris); *Ikposa* (Benin); *Ehiri* or *Ehuru* (Ibo); *Gujiya dan miya* (Hausa), *Ariwo*, *arigbo*, *Abo lakoshe*, or *eyi naghose* (Yoruba); *Ehinawosin* (Ikale), *Uyengben* (Edo), and *Fausse noix de muscade* (French). Inside the fruit of *Monodora myristica* are many seeds which are usually 1.5cm long and enclosed in a white sweet-smelling mash [6]. The researchers [7] and [8] reported that the seeds of *Monodora myristica* are principally used as a spice in various dishes and in seasoning soups and salads. Currently, the tendency to use the oil extracted from *Monodora myristica* to flavor popcorn has justified the use of the spice as a flavoring with good acceptability and no adverse effect. This was revealed in a study conducted by [9]. On the other hand, [10] reported that *Monodora myristica* seeds have a wide scope of curative effects which are applied in traditional medicine. Furthermore, [11], [4] divulged that the economic importance of *Monodora myristica* is based on the palatability of its seeds

which are loaded with oils, minerals, and proteins. This makes the plant food a potential plant protein that can complement most monotonous starchy staples consumed by many in developing countries.

Most processing methods, especially heat processing, have detrimental effects on the sensory properties of foods. [12] divulged that during food processing, flour undergoes changes such as gelatinization and pasting and this influences the consistency and stability of food products. The researchers, [13] reported that the use of flour in food processing depends largely on the understanding of its functional and pasting properties. Furthermore, [14] reported that pasting and functional properties of flour are parameters used to ascertain the appropriateness of its use as functional material in food and other industrial products. This is because of their effect on the consistency, sensory properties, and how consumers accept the finished products as revealed by [15].

Monodora myristica seeds are processed locally (in the regions of Sub-Saharan Africa) using various indigenous knowledge-based processing techniques like boiling, roasting, and frying for different duration of time. These traditional methods of processing greatly reduce their nutritional and economic/industrial value. This was revealed in a study conducted by [1], [2] Unfortunately, there is no

information on the effects of various processing methods (at defined time intervals) on the functional and pasting properties of *Monodora myristica* seeds.

The aim of this study was therefore to determine the impact of various cooking methods (boiling and roasting) and cooking times (10, 20, and 30min) on the functional and pasting properties of *Monodora myristica* seed flour so as to provide information that will culminate in the effective utilization of the seed flour in food and other industrial applications thereby expanding its usage.

II. MATERIALS AND METHODS

A. Reagents and Chemicals

Reagents of analytical grade from Sigma Aldrich Co., Ltd (Steinheim, Germany) were used for this study

B. Sample

Seeds of *Monodora myristica* were procured from a local market, in Ado-Ekiti, Ekiti State, Nigeria.

C. Sample Preparation

Foreign materials like dry leaves and stones were separated from *Monodora myristica* seeds. The cleaned seeds were thereafter split into seven groups and processed using the procedure described by [16] with minor modifications. The first group was raw and served as the control. The second, third, and fourth groups were boiled at 100 °C using tap water for 10, 20, and 30min respectively in a ratio of 1:3 (weights of seeds to the volume of water). The boiled seeds were dried in an oven at 100 °C for 5 h, dehulled manually with the use of mortar and pestle [8] and milled into fine flour using an electric blender. The fifth, sixth, and seventh groups were processed by roasting at 120 °C for 10, 20, and 30 min, respectively, dehulled manually with the use of mortar and pestle [8] and crushed into fine flour. Hulls were removed from raw (control) *Monodora myristica* seeds (first group) and these seeds were thereafter milled into fine flour.

D. Defatting of Flour Samples

Buchi 810 Soxhlet Fat Extractor (Flawil, Switzerland) with hexane [17] was used to defat flour samples for 4 h. The moisture content of the defatted samples was reduced by drying in an air convection oven (Gallenkamp, England) at 60 °C for 12 h [13]. Samples were subsequently wrapped in polythene bags labeled accordingly: CON: raw flour; BO10, BO20, BO30: flour samples from seeds boiled for 10, 20 and 30 min respectively; RO10, RO20, RO30: flour samples from seeds roasted for 10, 20, and 30 min respectively. They were thereafter kept in an airtight container in the refrigerator at 4 °C for further analysis [13].

E. Sample Analysis

The modified procedure described by [18] was adopted to determine the water absorption capacity of the defatted flour samples. The sample (1 g on dry weight basis) was transferred into a test tube containing 10ml distilled water, vortexed periodically for 10min. and centrifuged at 4500 rpm for 20 min. The supernatant was poured out and the test tube was turned upside down and left to drain for 5 min. Water absorption capacity was computed as the percentage of the

gram of water absorbed per gram of sample after weighing the residue.

The method of [19] as described by [20] was adopted to determine the oil absorption capacity. Sample-1g was transferred into a dry, clean centrifuge tube and the weight of the sample and tube was noted. Thereafter, 10ml of grand soya oil with a density 0.98 gcm⁻³ was poured into the centrifuge tube. A spatula (stainless steel) was used to thoroughly mix the sample with the soya oil. The suspension was centrifuged (Model No. L-708-2, Phillips Drucker, Oregon, USA) at 350×g speed for 15 min, and the supernatant was poured out. The centrifuge tube and its content were re-weighed. The gain in mass expressed as a percentage of oil bound was calculated as the oil absorption capacity of the sample.

Bulk density was determined using the procedure of [21]. A weighed 10 ml graduated measuring cylinder was carefully filled with the flour sample to the 10 ml mark and the bottom of the cylinder was tapped continuously until there was no further reduction of the sample level.

The method of [22] was adopted to determine the emulsifying capacity of flour samples. Sample- 0.5g was transferred into a graduated tube containing 3ml of distilled water. Cotton seed oil- 3 ml was added, and the mixture was aggressively mixed for 10 min with an agitator. The resultant emulsion was centrifuged at 2500 rpm for 30 min. The emulsifying capacity of flour samples was calculated by dividing the height of the emulsified layer by the height of the whole slurry and multiplying the result by 100.

Flour water slurry made by mixing 0.35 g flour with 12.5 ml distilled water in a water bath at 60 °C for 30 min as described by [23] was used to determine the swelling power and solubility of flour samples. A Superspeed centrifuge was used to centrifuge the slurries for 15 min at 1600 rpm. The evaporating dish was weighed and dried at 100 °C for 20 min and the supernatant was transferred into the dish. The solubility of flour samples was calculated by determining the difference in the weight of the evaporating dish. The residue after centrifugation was accurately weighed and divided by the original weight of flour samples on a dry basis to determine the swelling power of flour samples.

Rapid Visco-Analyser (RVA Model RVA 3D series 4) was used to determine the pasting properties of the defatted samples. Flour samples (3 g) were transferred into a clean and dry canister. Flour dispersion was obtained after thoroughly mixing the flour sample with distilled water (25 ml). The canister containing the flour dispersion was fitted into the RVA and heated from 50-95 °C with a holding time of 2 min and cooled to 50 °C with a 2min holding time. Heating and cooling were at a constant rate of 11.25 °C/min. Pasting properties- peak time, peak, trough, breakdown, setback, and final viscosity were read from the pasting profile using thermocline for windows software connected to a computer [24].

F. Calculation of Parameters

The following formula was used for calculation:

$$\text{Bulk density (g/ml)} = \frac{\text{weight of sample}}{\text{volume of sample}}$$

G. Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 21 at $p \leq 0.05$. Duncan's Multiple Range Test (DMRT) was employed to separate means.

III. RESULTS

Functional properties of raw and thermally processed *Monodora myristica* seed flours are displayed in Table I. The bulk density of raw and thermally processed samples was not significantly different ($P \geq 0.05$). Thermal processing did not significantly ($P \geq 0.05$) affect the water absorption capacity and swelling power of flour samples.

The suitability of flour as a functional ingredient in food and other industrial products is ascertained by its pasting properties. The effect of thermal processing on the pasting profile of defatted *Monodora myristica* seed flour is shown in Table II. Peak times of all thermally processed samples was not significantly different ($P \geq 0.05$).

IV. DISCUSSION

Water absorption capacity (WAC) ranged from 158 to 189%. Raw *Monodora myristica* seed flour had the lowest value (158%). There was no significant ($P \geq 0.05$) difference in the WAC of thermally processed (boiled and roasted) samples. The water absorption capacity (158%) of raw *Monodora myristica* seed flour compares favorably with 160% reported for dehulled *Monodora myristica* by [25] but is higher than 128.31% reported for dehulled *Azelia africana* seeds by [26]. However, these values are much lower than the values- 400% to 600% for jackfruit seed flour samples [27]. [28] reported that WAC is the water retained in food after filtration and centrifugation. A high water absorption capacity is important for product cohesiveness, hence, WAC is an important functional parameter in the production of ready-to-eat foods [29]. Furthermore, WAC has an effect on the quality of food products prepared by baking and partly depends on the protein content and particle size of flour [30]. The water absorption capacity of flour improves handling characteristics by allowing the food handler to add more

water during its processing. Flour with high WAC helps to retain the freshness of baked foods like cakes, sausage, and bread. The high WAC of boiled and roasted flours makes them suitable for use as soup thickeners and in food processes like baking that require the production of dough. [31], [32] reported that flour with high water absorption capacity improved the smoothness and consistency of baked goods. Lower WAC is advantageous in the preparation of thinner porridge with high caloric density per unit volume [32].

Oil absorption capacity (OAC) of defatted *Monodora myristica* flour samples ranged from 255 to 299%. Flours processed by boiling had significantly higher ($P \leq 0.05$) OAC. Sample BO30 had the highest value (299%). [33] reported that flours that underwent wet thermal processing had increased oil absorption capacities. The oil absorption capacity of raw defatted *Monodora myristica* seed flour is 255% which is higher than 91.8% reported for *Bombacopsis glabra* by [34] but lower than that of cowpea flour samples, 281–321% [35]. Oil absorption capacity depicts the emulsifying ability and the quantity of the oil that a food product can acquire through frying [28]. It is an important parameter in new food product development as it improves the flavor and mouth feel of food [27]. Excellent OAC of flour samples favors their use in food processes that requires mixing of oil such as baking [36]. Thus, *Monodora myristica* seed flour would be a good substitute for most legumes and oil seeds that are used as thickeners in liquid and semi-liquid foods. Also, the seed flour can be added to food to improve its taste thereby acting as a flavor retainer.

Emulsion capacity ranged from 48.85 to 55.58%. These values are lower than 97.2% reported for the defatted *Moringa* seed flour sample [37] but much higher than 35.25% reported for dehulled *Azelia africana* seeds [26]. Roasting did not significantly ($P \geq 0.05$) affect the emulsion capacity of *Monodora myristica* seed flour. Emulsion capacity shows the highest volume of oil that can be amalgamated by protein dispersion [38]. Emulsion capacity values of flour samples in this study show their appropriateness for strong emulsions that cannot easily aggregate into small lumps [39]. Therefore, these flour samples can be combined with wheat flour in food preparations since their values are much higher than the range (14.67 to 20.35%) reported for wheat flour by [40].

TABLE I: FUNCTIONAL PROPERTIES OF RAW AND THERMALLY PROCESSED *MONODORA MYRISTICA* SEED FLOURS

Parameters	Raw	RO10	RO20	RO30	BO10	BO20	BO30
Bulk density (g/ml)	0.59 ^a ±0.00	0.55 ^a ±0.06	0.57 ^a ±0.03	0.58 ^a ±0.04	0.56 ^a ±0.09	0.56 ^a ±0.06	0.55 ^a ±0.00
Emulsion capacity (%)	48.85 ^a ±0.11	53.99 ^a ±0.21	54.30 ^a ±1.46	54.10 ^a ±0.00	49.92 ^{bc} ±1.49	51.45 ^b ±0.01	55.58 ^a ±0.83
Oil absorption capacity (%)	255 ^d ±11.31	262 ^d ±0.00	267 ^{cd} ±4.23	275 ^{bcd} ±7.07	285 ^{abc} ±8.49	295 ^{ab} ±1.41	299 ^a ±16.97
Water absorption capacity (%)	158 ^b ±7.07	187 ^a ±11.31	186 ^a ±4.24	187 ^a ±0.00	185 ^a ±1.41	186 ^a ±8.49	189 ^a ±9.90
Swelling power (%)	5.22 ^b ±0.04	7.11 ^a ±0.16	7.09 ^a ±0.09	7.11 ^a ±0.14	7.12 ^a ±0.04	7.14 ^a ±0.07	7.10 ^a ±0.10
Solubility (%)	22.08 ^a ±0.00	12.03 ^c ±0.04	11.89 ^c ±0.30	8.07 ^f ±0.04	13.60 ^d ±0.30	16.59 ^e ±0.40	17.73 ^b ±0.24

Values with different superscripts are significantly different at $P \leq 0.05$.

TABLE II: PASTING PROPERTIES OF RAW AND THERMALLY PROCESSED *MONODORA MYRISTICA* SEED FLOUR

Pasting properties (RVU)	Raw	RO10	RO20	RO30	BO10	BO20	BO30
Peak Viscosity	23.80 ^a ±3.54	24.88 ^c ±0.13	26.69 ^{bc} ±0.16	35.25 ^a ±0.03	23.85 ^c ±0.00	24.15 ^c ±0.21	28.68 ^b ±0.04
Trough Viscosity	18.40 ^c ±0.58	19.81 ^b ±0.01	19.98 ^b ±0.13	23.00 ^a ±0.00	18.28 ^c ±0.10	18.00 ^c ±0.06	16.82 ^d ±0.04
Break down Viscosity	6.90 ^a ±0.03	6.33 ^b ±0.01	5.73 ^c ±0.00	5.39 ^d ±0.09	4.82 ^e ±0.03	3.78 ^f ±0.13	3.65 ^f ±0.04
Final Viscosity	28.70 ^b ±0.01	28.83 ^b ±0.06	29.33 ^{ab} ±0.17	30.31 ^a ±0.01	28.07 ^{bc} ±0.00	27.21 ^{cd} ±1.44	26.30 ^d ±0.06
Setback Viscosity	11.30 ^d ±0.00	12.41 ^c ±0.09	13.11 ^b ±0.17	14.02 ^a ±0.00	10.55 ^e ±0.11	10.01 ^f ±0.01	8.79 ^a ±0.18
Peak Time	4.96 ^b ±0.11	6.27 ^a ±0.03	6.31 ^a ±0.00	6.34 ^a ±0.07	6.29 ^a ±0.09	6.25 ^a ±0.01	6.30 ^a ±0.07

Values with different superscripts are significantly different at $P \leq 0.05$.

Processing did not significantly ($P \geq 0.05$) affect the bulk density of defatted *Monodora myristica* seed flour (Table I). However, [13] reported that the bulk density of *Moringa oleifera* seed flour samples significantly ($P \leq 0.05$) decreased when they were processed by fermentation. The bulk density values recorded in this study were slightly lower than that of taro flours (0.57 to 0.71 g/ml) [41]. They were also lower than the value 0.61 g/ml reported for raw Jackfruit seed flour [42]. Bulk density measures how heavy a flour sample is and it's an important parameter for ascertaining packaging requirements, texture, mouth feel, and material handling in the food industry [43]. Therefore, the low bulk density values of flour samples in this study show that they are suitable for packaging. Defatted *Monodora myristica* seed flour samples would also be suitable for use in the formulation of complementary food for infants. According to [44], high bulk reduces the caloric and nutrient intake of a child making the child unable to eat enough to satisfy his/her energy nutrient requirements.

The swelling power of flour samples ranged from 5.22 to 7.14% and these values are higher than the 4.77% reported for Jackfruit seed flour by [43]. Thermal processing did not significantly ($P \geq 0.05$) affect the swelling power of *Monodora myristica* seed flour samples. Swelling power shows the capability of starch to absorb water and expand [45]. It has a direct relationship with WAC and could depend on the bond existing within the starch granules [46], [47]. [48] opined that swelling power is the ratio of amylose to amylopectin and depends on the characteristics of each fraction.

Solubility of seed flour samples ranged from 8.07% to 22.08%. Sample RO30 had the lowest value, and the control sample (raw) had the highest value. This was comparable to the values obtained by [49] (10.12% to 23.42%) for cowpea flour from different varieties. On other hand, [50] reported values ranging from 8.24% to 4.48% for Jackfruit seed flour samples. Boiled samples had significantly higher solubility than the roasted samples. [50] reported that solubility increased with cooking and this increase is a result of the reduction in the chain length of starch molecules and the weakening of hydrogen bonds holding them together. Solubility simply means the ability of a solid to dissolve or melt in water or an aqueous solution. It shows the extent of intermolecular cross bonding within the starch granule.

The behavior of starches when they are cooked, and the viscosity of the resulting pastes can be analyzed with a Rapid Visco Analyzer (RVA) [51]. RVA breakdown is a result of the disordering of the gelatinized starch granule structure and the degree of breakdown depends on the variation between the viscosity when enlarged gelatinized granules existed and the viscosity when gelatinized granules are partially or completely disordered [52]. Each viscosity is associated with a specific feature or attribute [51]. Peak viscosity (PV) ranged from 23.80 to 35.25RVU. The sample thermally processed by roasting-RO30 had the highest value (35.25RVU). There was a significant ($P \leq 0.05$) difference in the peak viscosity of defatted *Monodora myristica* seed flour samples (Table II). PV is the point of equilibrium between enlargement and disintegration of starch granules [53], [54]. [55] divulged that starch granules with high PV have weaker cohesive attraction within them and would break down easily. The PV of cooked

starch granules depends on their swelling capacity and the ease with which they dissolve in an aqueous medium. Flour with low PV generally has lower thickening power than flour with high PV and this could be as a result of factors such as protein and fat interaction. The researchers [15] observed that cooking by extrusion reduced the PV of extrudates. Flour samples processed by roasting would have excellent gel power and gel-making capacity than boiled flour samples due to their high PV. They would also be useful in food formulations that require high concentration power at high temperatures in the food industry. However, flour samples processed by boiling could also be useful in similar applications considering their PV values which ranged from 23.85 to 28.68RVU.

Trough (holding strength) viscosity (TV) ranged from 16.82 to 23.00RVU. Sample BO30 had the lowest value of 16.82RVU. TV is the lowest viscosity value in the constant temperature phase of the RVA pasting profile [56]. It is the stage at which viscosity gets to its minimal during heating or cooling and it evaluates the capability of paste to resist disintegration during cooling. Roasted sample RO30, had the highest TV value.

Breakdown viscosity (BD) ranged from 3.65 to 6.90RVU. Flour samples processed by roasting had higher breakdown viscosity than boiled samples. Breakdown viscosity measures the likelihood of enlarged starch granules bursting at high temperatures and indicates paste stability [57]. High BD lowers the capability of a sample to successfully resist heating and shear stress during cooking [46]. Therefore, boiled *Monodora myristica* seed flour samples would resist heating and shear stress more than roasted and raw flour samples that had high BD values.

Values for final viscosity (FV) ranged from 26.30 to 30.31RVU. This variation could be a result of the aggressive impact of cooling on viscosity and the regrouping of starch granules in flour samples [56]. Roasted sample RO30 had the highest value (30.31RVU) while sample BO30 had the lowest value. [54] reported that FV shows or reveals the capability of flour to develop a viscous paste after thermal processing and cooling. Flour samples with high amylose content would have higher FV than flour with low amylose content because the FV of the starch paste is directly linked to its amylose content as reported by [58]. There was a progressive increase in the final viscosity of roasted *Monodora myristica* seed flour samples (28.83RVU (RO10) to 30.31RVU (RO30) and this could be a result of the positioning of the chains of amylose in the starch [59].

Setback viscosity (SB) of flour samples varied between 8.79 and 14.02RVU. Roasted flour sample RO30 had significantly ($P \leq 0.05$) high setback viscosity while boiled flour sample BO30 had significantly ($P \leq 0.05$) low SB. Setback viscosity shows the ability of cooked paste to withstand deterioration and it can be used to determine the shelf life of a product produced from the flour [45]. [60] suggested that low SB could be a result of low amylase with high molecular weight in a flour sample. The higher the SB of a flour sample, the lower the rate of deterioration during cooling of the product processed from it [15], [61]. Therefore, roasted flour samples would have less tendency to deteriorate compared to raw and boiled samples due to their high (12.41 to 14.02RVU) SB. Nevertheless, raw and boiled *Monodora*

myristica seed flour samples would be useful in confectionery industries.

Peak time which is the stage when peak viscosity occurred ranged from 4.96 to 6.34min. The peak time indicates the minimal time and temperature needed to process flour by cooking [62]. It also indicates how easily a food product can be cooked. Thermal processing had no significant ($P \geq 0.05$) effect on the peak time of *Monodora myristica* seed flour. However, thermally processed samples generally had a significantly ($P \leq 0.05$) higher peak time than the raw sample. The same observation was made by [49] who reported that treated cowpea samples (boiled, roasted) generally had significantly higher peak time than untreated cowpea samples.

V. CONCLUSION

No significant ($P \geq 0.05$) difference existed in the bulk density of raw and thermally processed *Monodora myristica* seed flours. All the flour samples had the ability to form a paste in hot water below the boiling point of water making it possible to save costs during commercial production. Flour samples processed by roasting were more capable of resisting breakdown and would form a gel with higher strength than other flour samples. On the other hand, they had the lowest capability to withstand heating and shear stress when thermally processed.

CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

REFERENCES

- [1] Burubai WE, Amula P, Daworiye T, Suwadi E, Nimame P. Proximate composition and some technological properties of African nutmeg (*Monodora myristica*) seeds. *Elect. J. Environ. Agric. Food Chem.*, 2009;8(5): 396–402.
- [2] Ojiako OA, Igwe CU, Agha NC, Ogbuji CA, Onwuliri VA. Protein and amino acid compositions of *Sphenostylis stenocarpa*, *Sesamum indicum*, *Monodora myristica* and *Azalia Africana* seeds from Nigeria. *Pak. J. Nutr.*, 2010;9(4): 368–372. DOI: 10.3923/pjn.2010.368.372.
- [3] Feyisayo AK, Oluokun OO. Evaluation of antioxidant potentials of *Monodora myristica* (Gaertn) dunel seeds. *Afr. J. Food Sci.*, 2013;7(9): 317–324. DOI: 10.5897/AJFS2013.
- [4] Enabulele SA, Oboh FOJ, Uwadiae EO. Antimicrobial, nutritional and phytochemical properties of *Monodora myristica* seeds. *IOSR J. Pharm. Biol. Sci.* 2014;9(4): 1–6. DOI:10.9790/3008-09430106.
- [5] Abdou Bouba A, Ponka R, Njintang Yanou N, El-Sayed MAH, Montet D, Scher J, Mbofung CM. Amino acid and fatty acid profile of twenty wild plants used as spices in Cameroon. *Am. J. Food Sci. Technol.*, 2016; 4(2): 29–37. DOI:10.12691/ajfst-4-2-1.
- [6] Onyenibe NS, Fowokemi KT, Emmanuel OB. African Nutmeg (*Monodora myristica*) lowers cholesterol and modulates lipid peroxidation in experimentally induced hypercholesterolemic male wistar rats. *Int. J. Biomed. Sci.*, 2015; 11(2):86–92.
- [7] Erukainure OI, Oke OV, Owolabi FO, Kayode FO, Umanhonlen EE, Aliyu M. Chemical properties of *Monodora myristica* and its protective potentials against free radicals in vitro. *Oxidants, Antioxid. Med. Sci.*, 2012;1(2): 127–132. doi: 10.5455/oams.080712.or.009.
- [8] Olatoye KK, Fapojuwaa OO, Olorunsholaa JA, Ayorinde JO. Potentials of African Nutmeg (*Monodora myristica*) as a Flavourant in Cookie Production. *Int. J. Food Studies*, 2019;8:1–12.
- [9] Enwereuzoh RO, Damaris CO, Uzoukwu UN, Uyanwa CN. Flavor extraction from *monodora myristica* and *tetrapleura tetraptera* and production of flavored popcorn from the extract. *European J. Food Sci. Technol.*, 2015;3(2): 1–17.
- [10] Agiriga AN, Siwela M. *Monodora myristica* (Gaertn.) Dunal: a plant with multiple food, health and medicinal applications: a review. *Am. J. Food Technol.*, 2017;12(4): 271–284. DOI: 10.3923/ajft.2017.271.284
- [11] Akinwunmi KF, Oyedapo OO. Evaluation of antioxidant potentials of *Monodora myristica* (Gaertn.) dunel seeds. *Afr. J. Food Sci.*, 2013;7(9): 317–324. https://doi.org/10.5897/AJFS2013.1020
- [12] Iwe MO, Agiriga AN. Pasting properties of Ighu – a cassava meal. *J. Food Proc. Preser.*, 2014;38(6): 2209–2222. https://doi.org/10.1111/jfpp.12201.
- [13] Oloyede OO, James S, Ocheme OB, Chinma CE, Akpa VE. Effects of fermentation time on the functional and pasting properties of defatted *Moringa oleifera* seed flour. *Food Sci. Nutr.*, 2016;4(1): 89–95. DOI: 10.1002/fsn3.262.
- [14] Aviara NA, Igbeka JC, Nwokocho LM. Effect of drying temperature on physicochemical properties of cassava starch. *Int. Agrophys.*, 2010;24(3): 219–225.
- [15] James S, Nwabueze TU. Influence of extrusion condition and defatted soybean inclusion on the functional and pasting characteristics of extruded African breadfruit (*Treculia africana*) flour blends. *Food Sci. Qual. Manage.*, 2014;34: 26–33.
- [16] Mbah BO, Eme PE, Ogbusu OF. Effect of cooking methods (boiling and roasting) on nutrients and anti-nutrients content of *Moringa oleifera* seeds. *Pak. J. Nutr.*, 2012; 11(3): 211–215. DOI: 10.3923/pjn.2012.211.215.
- [17] Laroche M, Perreault V, Marciniak A, Gravel A, Chamberland J, Doyen A. Comparison of conventional and sustainable lipid extraction methods for the production of oil and protein isolate from edible insect meal. *Foods*, 2019;8(11):572. doi: 10.3390/foods8110572
- [18] Phillips RD, Chinnan MS, Branch AL, Miller J, Mcwatters KH. Effects of pre-treatment on functional and nutritional properties of cowpea meal. *J. Food Sci.*, 1988;53:805–809.
- [19] Sosulski FW. The centrifuge methods for determining flour absorption in hard red spring wheat. *Cereal Chem.* 1962;39: 344–349.
- [20] Abbey BW, Ibeh CO. Functional properties of raw and heat processed cowpea (*Vigna unguiculata walp*) flour. *Food Sci.*, 1988;53(6): 1775–1777. https://doi.org/10.1111/j.1365-2621.1988.tb07840.x.
- [21] Onwuka GI. *Food Analysis and Instrumentation (Theory and practice)*. Second edition Naphthali Prints, Lagos, Nigeria. 2018;353-359.
- [22] Beuchat LR, Cherry JB, Quinn MR. Physicochemical properties of peanut powder as affected by proteolysis. *J. Agric. Food Chem.*, 1975;23(4): 616–620. https://doi.org/10.1021/jf60200a045.
- [23] Crosbie GB. The relationship between swelling properties, paste viscosity and boiled noodle quality in wheat flours. *J. Cereal Sci.*, 1991;13(2):145–150. https://doi.org/10.1016/S0733-5210(09)80031-3.
- [24] Newport Scientific. Application manual for rapid visco-analyzer using thermocline for windows, Newport Scientific Pty Ltd, Australia, 1998; 2–26.
- [25] Ogunbenle HN, Adu TO. Proximate composition and functional properties of dehulled African Nutmeg (*Monodora myristica*). *Pak. J. Sci. Ind. Res. Ser. A. Phys. Sci.*, 2012;55(2): 80–85.
- [26] Ogunbenle HN, Omaejalile M. Functional and anti-nutritional properties, in-vitro protein digestibility and amino acid composition of dehulled *Azalia africana* seeds. *Pak. J. Sci. and Ind. Res.*, 2010;53(5): 265–270.
- [27] Eke- Ejiofor J, Beleya EA, Onyenorah NI. The Effect of processing methods on the functional and compositional properties of Jackfruit seed flour. *Int. J. Nutr. Food Sci.*, 2014;3(3):166–173. doi: 10.11648/j.ijnfs.20140303.15.
- [28] Falade KO, Okafor CA. Physical, functional, and pasting properties of flours from corms of two Cocoyam (*Colocasia esculenta* and *Xanthosoma sagittifolium*) cultivars. *J. Food Sci Technol.*, 2015;52(6): 3440–3448. doi: 10.1007/s13197-014-1368-9.
- [29] Houssou P, Ayernor GS. Appropriate processing and food functional properties of maize flour. *Afri. J. Sci. Technol.*, 2002;3(1): 126–131. DOI: 10.4314/ajst.v3i1.15297.
- [30] Kulkarin KD, Kulkarin DN, Ingle UM. Sorghum malt-based weaning formulations, preparation, functional properties and nutritive value. *Food Nutr. Bull.*, 1991;13(4): 327–332.
- [31] Aprianita A, Vasiljesic T, Banicova A, Kasapis S. Physicochemical properties of flours and starches from traditional Indonesian tubers and roots. *J. Food Sci. Technol.*, 2014;51(12):3669–3679. doi: 10.1007/s13197-012-0915-5.
- [32] Ramashia SE, Gwata ET, Medows-Taylor S, Anyasi TA, Jideani AIO. Some physical and functional properties of finger millet (*Eleusine coranana*) obtained in Sub-Saharan Africa. *Food Res. Int.*, 2017;104: 110–118. doi: 10.1016/j.foodres.2017.09.065.
- [33] Ma Z, Boye J, Simpson B, Prasher S, Monpetit D, Malcolmson L. Thermal processing effects on the functional properties and

- microstructure of lentil, chickpea, and pea flours. *Food Res. Int.*, 2011;44(8): 2534–2544. <https://doi.org/10.1016/j.foodres.2010.12.017>
- [34] Olaofe O, Akintayo ET, Adeyeye EI, Adubiabo HO. Proximate composition and functional properties of bulma cotton (Bomb capsis) seeds. *Egy. J. Food Sci.*, 2006; 34(1): 81–90.
- [35] Olaofe O, Adeyemi FO, Adediran GO. Amino acid and mineral composition and functional properties of some oil seeds. *J. Agric. Food Chem.*, 1994;42(4): 878–881. <https://doi.org/10.1021/jf00040a007>.
- [36] Fagbemi TN. Effect of blanching and ripening on functional properties of plantain (*Musa spp*) flour. *Foods Hum. Nutr.*, 1999;54(3): 261–269. doi: 10.1023/a:1008153404357.
- [37] Ogunsina BS, Indira TN, Bhatnagar AS, Radha C, Sukumar D, Gopalakrishna AG. Quality characteristics and stability of Moringa oleifera seed oil of Indian origin. *J. Food Sci. Technol.*, 2014 ;51(3): 503–510. doi: 10.1007/s13197-011-0519-5.
- [38] Enujiugha VN, Badejo AA, Iyiola SO, Oluwamukomi MO. Effect of germination on the functional properties of African oil bean (*Pentaclethra macrophylla* Benth) seed flour. *J. Food Agric. Environ.*, 2003;1(3&4): 72–75.
- [39] Subago A. Characteristics of hyacinth bean (*Labtab purpureus* L.) sweet seeds from Indonesia and their protein isolate. *Food Chem.*, 2006;95(1):65–70. DOI: 10.1016/j.foodchem.2004.12.042.
- [40] Ukoni AN, Richard CP, Abasiokong SK. Effect of processing on the proximate, functional and anti-nutritional properties of cocoyam (*Xanthosoma mafa* S.) flour. *Nig. Food J.*, 2017;35(2): 9–17.
- [41] Njintang YN, Mbofung CMF, Moates KG, Parker L, Fauld CB, Smith AC. Functional properties of five varieties of taro flour and relationship to creep recovery and sensory characteristics of achu (taro based paste). *J. Food Eng.*, 2007;82(2): 114–120.
- [42] Odoemelam SA. Functional properties of raw and heat processed jackfruit seeds flour. *Pak J. Nut.*, 2005; 4(6): 366–370.
- [43] Ocloo FCK, Bansa D, Boatin R, Adom T, Agbemavor WS. Physicochemical, functional and pasting characteristics of flour produced from jackfruits (*Artocarpus heterophyllus*) seeds. *Agric and Bio. J. North Am.*, 2010;1(5): 903–908. doi:10.5251/abjna.2010.1.5.903.908.
- [44] Onuoha OG, Chibuzo E, Badau M. Studies on the potential of malted *Digitaria exilis*, *Cyperus esculentus* and *Colocasia esculenta* flour blends as weaning food formulation. *Nig. Food J.*, 2014;32(2): 40–47. [https://doi.org/10.1016/S0189-7241\(15\)30116-8](https://doi.org/10.1016/S0189-7241(15)30116-8).
- [45] Jude-Ojei BS, Lola A, Ajayi IO, Seun I. Functional and pasting properties of maize ‘Ogi’ supplemented with fermented Moringa seeds. *J. Food Proc. & Technol.*, 2017; 8(5):674. DOI: 10.4172/2157-7110.1000674.
- [46] Adebowale YA, Adeyemi IA, Oshodi AA. Functional and physicochemical properties of flours of six *Mucuna* species. *Afr. J. Biotechnol.*, 2005;4(12): 1461–1468.
- [47] Safo-Kantanka KO, Acquistucci R. The Physico-chemical properties of cassava starch in relation to the texture of the cooked root. *Ghana J. of Agric. Sci.*, 1996;28: 69–80. DOI: 10.4314/gjas.v28i1.2010.
- [48] Rickard JR, Asaoka MA, Blanshard JMV. The physicochemical properties of cassava starch. *Trop Sci.*, 1991;31: 189–207.
- [49] Adegunwa MO, Bakare HA, Alamu EO, Abiodun OK. Processing effects on chemical, functional and pasting properties of cowpea flour from different varieties. *Nig. Food J.*, 2012;30(1): 67–73. [https://doi.org/10.1016/S0189-7241\(15\)30015-1](https://doi.org/10.1016/S0189-7241(15)30015-1).
- [50] Eke-Ejiofor J, Barber LI, Kiin-Kabari DB. Effect of Pre-Boiling on the Chemical, functional and Pasting Properties of Rice. *J. Agric. Bio. Sci.*, 2011; 2(7): 214–219.
- [51] Kesarwani A, Chiang PY, Chen SS. Rapid Visco Analyzer measurements of japonica rice cultivars to study interrelationship between pasting properties and farming system. *Int. J. Agron.* 2016; 1-7. <https://doi.org/10.1155/2016/3595326>
- [52] Han X-Z, Hamaker BR. Amylopectin fine structure and rice starch paste breakdown. *J. Cereal Sci.* 2001;34(3): 279–284. <https://doi.org/10.1006/jcrs.2001.0374>
- [53] Liu Q, Donner E, Yin Y, Huang RL, Fan MZ. The physicochemical properties and in vitro digestibility of selected cereals, tubers and legumes grown in China. *Food Chem.* 2006;99(3): 470–477. <https://doi.org/10.1016/j.foodchem.2005.08.008>
- [54] Shimel AE, Meaza M, Rakshit S. Physic-chemical properties, pasting behaviour and characteristics of flour and starch from improved bean (*Phaseolus vulgaris* L.) Varieties Grown in East Africa. *CIGRE*, 2006;8: 1–18.
- [55] Hoover R. Composition, molecular structure, and physicochemical properties of tuber and root starches: a review. *Carbohydr Polym.*, 2001;45(3): 253–267. [https://doi.org/10.1016/S0144-8617\(00\)00260-5](https://doi.org/10.1016/S0144-8617(00)00260-5).
- [56] Iwe MO, Onyeukwu U, Agiriga AN. Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. *Cogent Food Agric.*, 2016;2(1): 1–10. <https://doi.org/10.1080/23311932.2016.1142409>.
- [57] Kaur M, Singh N. Studies on functional, thermal and pasting properties of flour from different chick pea cultivars. *Food Chem.*, 2005;91(3): 403–411. DOI: 10.1016/j.foodchem.2004.06.015.
- [58] Lii CY, Tsai M, Tseng KH. Effect of amylose content on rheological properties of rice starch. *Cereal Chem.*, 1996;73(4):415–420.
- [59] Flores-Farias F, Martinez-Bustos Y, Salinas-Moreno YK, Chang JS, Hernandez R, Rios JE. Physicochemical and rheological characteristics of commercial nixtamalised Mexican corn flours for tortillas. *J. Sci. Food Agric.*, 2000;80(6): 657–664. DOI: 10.1002/(SICI)1097-0010(20000501)80:6<657::AID-JSFA576>3.0.CO;2-J.
- [60] Peroni FHG, Roche TS, Franco CML. Some structural and physicochemical characteristics of tuber and root starches. *Food Sci. Tech. Int.*, 2006;12(6): 505–513. <https://doi.org/10.1177%2F1082013206073045>.
- [61] Ikegwu OJ, Okechukwu PE, Ekumenkana EO. Physicochemical and pasting characteristics of flour and starch from Achi (*Brachystegia eurycoma*) seed. *J. Food Tech.*, 2010;8(2): 58–66. DOI: 10.3923/jftech.2010.58.66.
- [62] Chinma CE, Adewuyi O, Abu OJ. Effect of germination on the chemical, functional and pasting properties of flour from brown and yellow varieties of tiger nut (*Cyperus esculentus*). *Food Res. Int.*, 2009;42(8): 1004–1009. <https://doi.org/10.1016/j.foodres.2009.04.024>.