Impact of Processing on Physical, Chemical and Pasting Properties of Tamarind (*T. indica*) Seed Flour

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ABSTRACT: Tamarind seed is a discarded waste material from the tamarind pulp industry. The seed contains plethora of nutrients, however its application as food ingredient in Nigeria is limited. This study investigated the impact of processing techniques on physical (colour), proximate, mineral, anti-nutrient and pasting properties of tamarind seed flour using standard methods. Unprocessed seeds (sample A) served as the control, soaked seeds (sample B), roasted seeds (sample C) and autoclaved seeds (sample D). The obtained flour samples were analysed for the physical (colour), proximate, mineral, anti-nutrient and pasting properties using standard methods. Colour values (L*) of seed flour decreased whereas a* and b* values increased in processed flours compared to the control. Raw and processed tamarind seed flours are composed mainly of carbohydrate (65.0-75.2%) and protein (2.3-12.7%) with minuscule quantities of dietary fibre (3.50-7.10%), fat (5.4-6.8%) and ash (1.25-2.08%). The results revealed the following ranges in mineral concentrations: calcium (11.72-18.76mg/100g), magnesium (125.48-152.55mg/100g), potassium (224.49-487.37mg/100g) and iron (22.34-31.04mg/100g). Boiling, autoclaving and roasting significantly ($p \leq 0.05$) altered the anti-nutritional contents of tamarind seeds. There exist variation in the pasting viscosities with the control and processed tamarind flours being significantly different ($p \leq 0.05$). The study highlighted that roasting of the seeds could eliminate the anti-nutrients and improved the quality of seeds compared to soaking and autoclaving processes. Exploring the potential of tamarind seeds for human consumption will clearly reduce the over-dependence on common legumes as protein source in marginalised communities.

Wild plants play very significant roles in the diet of people in the developing world and are of great importance during food scarcity caused by economic hardship and incessant political unrest. Some wild fruits found in Nigeria include *Spondias mombin, Tamarind indica and Mordii whytii e*.t.c. Tamarind (*Tamarindus indica* Linn) is a member of the family *Leguminosae* (Fabaceae). It is native to dry Savannah of tropical Africa (Mohamed *et al*., 2015); however it has been introduced and naturalized worldwide in over 50 countries. The major production areas are in the Asian countries such as India and Thailand, but also in Bangladesh, Sri Lanka, Thailand and Indonesia. Minor producing countries in Africa are Senegal, Gambia, Kenya, Tanzania and Zambia (El-Siddig *et al.*, 2006). Commercial scale production of tamarind has not being exploited in Nigeria though it is widely distributed across some ecological zones (Akajiaku *et al.*, 2014). Tamarind fruit has two different varieties that are sweet and sour. Sweet tamarind fruit is harvested ripe and directly consumed whereas the sour

variety is processed into a range of value-added product. Tamarind seed is a by-product of the tamarind pulp industry. Tamarind pods contain 1-10 seeds, which are irregularly shaped, flattened or rhomboid. Seeds are very hard, shiny, reddish, or purplish brown. They are embedded in the pulp, lined with a tough parchment resembling a membrane, and joined to each other with tough fibres (Kumar and Bhattacharya, 2008). Tamarind seeds are rich sources of protein, crude fibre and carbohydrate and mineral elements especially potassium and magnesium (Ajayi *et al.*, 2006). However, it is imperative to know that despite numerous identified nutritional benefits of the seeds, its use as ingredient in food formulation in Nigeria is limited. The seed is a typical discarded waste material from the tamarind industry. Most importantly, the presence of tannin, phytic acid, hydrogen cyanide, trypsin inhibitor activity and phytohaemaglutin activity in the seed testa makes the whole seed unsuitable for consumption (Akajiaku *et al.*, 2014) though the seeds become edible after soaking and

boiling in water, which removes the seed coat (El-Siddig *et al.*, 2006). Likewise, tamarind seeds could be roasted, seed coats removed mechanically, soaked overnight in the water and eaten with the addition of salt or sugar as reported by Gitanjali *et al.* (2020). The roasted seeds have been reported to be superior to groundnuts in flavour (ICRAF, 2007). In view of the overall chemical composition of tamarind seeds, this work explores the effect of processing methods on physical, chemical, functional and pasting properties of the tamarind seed flour in a semi-arid region.

MATERIALS AND METHODS

Materials: The main raw material used in this project was tamarind fruit pods which was purchased from Baryara market in Bauchi state, North East Nigeria.

Sample preparation: Tamarind fruit pods were manually cracked and from each pod the pulp containing seeds was separated along with the fibrous strands. Tamarind seeds were prepared using the method described by Silva *et al.* (2020). The seed pulps were soaked for 12 hr in clean water (1: 3w/v) to allow complete removal of the pulp and fibrous strands. The seeds were later washed with distilled water and dried in an oven at 60ºC for 6 hr. The dried seeds were stored in airtight zip-lock bags.

Control sample: Dry tamarind seeds (500g) were crushed using a pestle and dehulled. The crushed tamarind seeds were winnowed to remove the hulls.

Dehulled tamarind seeds were milled into flour using attrition mill. The flour was sifted through a 1-mm mesh size sieve and stored in air-tight zip-lock bags prior to the analyses. This served as sample A.

Soaked sample: Five hundred grams (500g) of the seeds were soaked in tap water for 72 hr. The soaked tamarind kernels were then dehulled by rubbing in between hand palms. The dehulled seeds were rinsed with water, sundried for 24 hr and milled to flour using attrition mill. The flour was sifted through a 1-mm mesh size sieve and stored in air-tight zip-lock bags prior to the analyses. This served as sample B.

Roasted sample: A portion of the tamarind seeds (500g) were roasted in hot sand (125-175ºC) for 8 min. The roasted seeds were dehulled by rubbing in between hand palms and winnowed. Dehulled seeds were then milled to flour using attrition mill. The flour was sifted through a 1-mm mesh size sieve and stored in air-tight zip-lock bags prior to the analyses. This served as sample C.

Autoclaved sample: Five hundred grams (500g) of the seeds were autoclaved at 121ºC for 15 min. The autoclaved seeds were then rinsed with water, sundried for 24 hr and milled to flour using attrition mill. The flour was sifted through a 1-mm mesh size sieve and stored in air-tight zip-lock bags prior to analyses. This served as sample D. The different flour prepared from tamarind seeds is presented in Figure 1.
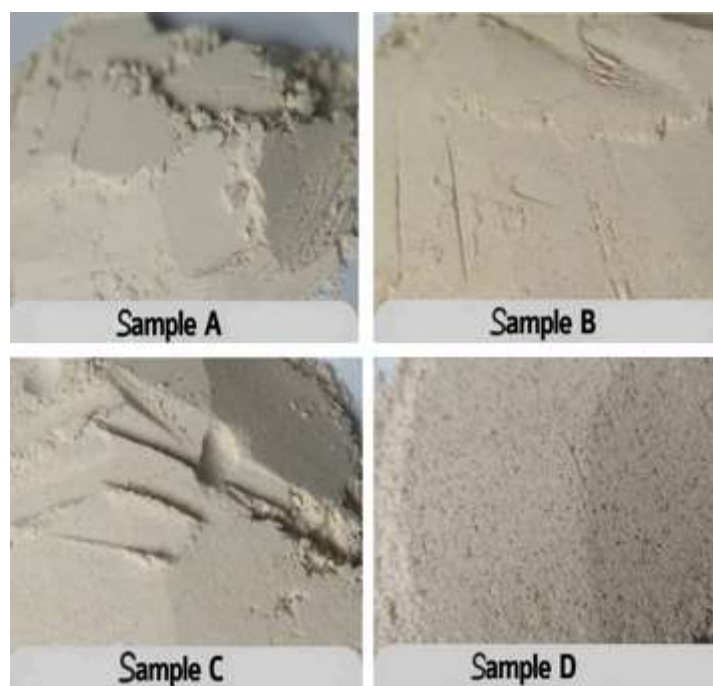

Fig 1. Tamarind seed flours
A-Unprocessed tamarind flour (control); B-Soaked tamarind flour; C-Roasted tamarind flour; D-Autoclaved tamarind flour

Measurement of physical property (colour): The colour of different flour samples was measured using the Konica Minolta Spectrophotometer (CR- 410, Japan). The flour (30g) was placed in the sample holder and the surface colour was measured at three different positions. The colour readings were displayed as L*a* b* values where L (100 = white; 0 = black) is an indication of lightness; *a** measures chromaticity, with positive values indicating redness and negative values indicating greenness; while *b** also measures chromaticity, with positive values indicating yellowness and negative values indicating blueness. ΔE_{ab} is the difference between two colours designated as two points in the Lab colour space. With values assigned to each of the L, a, and b attributes of two colours, simple geometry can be used to calculate the distance between their two placements in the Lab colour space. ΔE_{ab} is calculated using the formula:
$$\Delta E_{ab} = \sqrt{(L_1-L_2)^2 + (a_1-a_2)^2 + (b_1-b_2)^2}$$

Determination of chemical constituents: The flour samples were analyzed for protein, crude lipid, crude fibre and ash, according to the standard methods described by AOAC (2012). Estimation of carbohydrates occurred by difference, following the schematic formula: [100 - (lipids + crude protein + ash + crude fibre). Conversion values were used to determine the calorific value: 4 kCal/g for carbohydrate, 4 kCal/g for protein, and 9 kCal/g for lipid. All analyses were performed in three repetitions.

Potassium was determined using flame photometry (Corning, UK Model 405). The other elemental contents (calcium, magnesium and iron) were determined, after wet digestion of sample ash with a mixture of concentrated nitric acid, sulphuric acid and perchloric acid (10:0.5:2, v/v) using Atomic Absorption Spectrophotometer (AAS, Hitachi Z6100, Tokyo, Japan). All analyses were performed in three repetitions.

The chemical method described by Maga (1982) was used to determine the phytate content. Titration method was used to determine the oxalate content according to Day and Underwood (1986). Alkaloid content was determined gravimetrically as reported by Sreevidya and Mehrotra (2003). Trypsin Inhibitor Activity (TIA) was determined according to the procedure described by Prokopet and Unlenbruck (2002). All analyses were performed in three repetitions.

Determination of pasting properties: The pasting behaviour of the flour samples was measured in a Rapid Visco Analyzer (Model: RVA-4, Newport Scientific Pty. Ltd., Sydney, Australia, 1995) and Thermocline for Windows software was used to evaluate the pasting properties. The viscogram profile shows the relationships between time, viscosity, and temperature during cooking process.

Statistical Analysis: Determinations were carried out in triplicate and the errors were reported as standard deviation from the mean. Analysis of Variance (ANOVA) was performed and the least significant differences were calculated with the Statistical Package for Social Scientist (SPSS) software for Windows, version 16.00; SPSS Inc., Chicago IL, USA using the Analysis of Variance test (ANOVA one way) with Tukey's post-hoc. A significance level of 5.0% was established for rejection of the null hypothesis.

RESULTS AND DISCUSSION

Effect of processing methods on the colour of tamarind seed flours: Results in Table 1 indicate the existence of significant differences between the colour values of processed tamarind seeds compared to the control. The measurements with the Chroma Meter system (CIELab) showed highest L* value for raw tamarind flour (90.58) than other flour samples. The observation points to the fact that raw flour is whiter than other flour samples. The coloration of the tamarind flour when subjected to soaking, autoclaving or roasting became darker when compared to unprocessed sample. Impairment of colour of tamarind flour during roasting and autoclaving may be due to the continued heating process that encourages oxidation of the natural dyes in the flour and the interaction between atmospheric oxygen and the inherent enzymes as reported by Mahmoud and Abdel-Halim (1994). A similar trend was observed in the soaked sample though the flour was lighter (higher L* value) compared to autoclaved or roasted tamarind seeds. Redness (a*) value ranged from 2.72 to 5.91 and yellowness (b*) value ranged from 12.92 to 17.53. The colour attributes varied significantly when tamarind flours were made from the soaked, autoclaved or roasted seeds. Colour of flour is important regarding its application in food system as pigmentation found in such ingredient will be noticeable in finished products which in turn affect the consumer acceptability. In essence, colour is very important in the choice of food ingredient by consumers; hence it is advisable to consider the impact of darker colour presented by processed tamarind seed flour in food formulations. The symbol ΔE_{ab} indicates the differences between colour of the control sample (unprocessed) and processed flour samples. The ΔE_{ab} value of 5.54 between the raw (control) and soaked flour shows that differences between the flours were perceptible at a glance. Similarly, the ΔE_{ab} value of 10.26 of raw and roasted flour shows that differences

between the flours were perceptible. However, autoclaving of the tamarind seeds has been shown to have an effect on the colour of flour in that the colours of raw flour and autoclaved flour were perceptibly opposite, but still appear similar as indicated in ΔE_{ab} value of 18.44. It is important to note that colour differences affect consumer acceptability of products.

Table 1: Colour attributes of tamarind seed flour

Samples	L*	a*	b*	ΔE_{ab}
A	90.58[d] ±0.02	2.72[a] ±0.14	14.81[b] ±0.11	Control
B	85.76[c] ±0.07	2.90[ab] ±0.03	17.53[d] ±0.03	5.54±0.02
C	80.72[b] ±0.05	5.01[b] ±0.01	16.48[c] ±0.02	10.26±0.04
D	72.52[a]±0.03	5.91[c] ±0.06	12.92[a] ±0.07	18.44±0.03

Mean± standard deviation of triplicate determination
Key a-d: Means with the same superscripts within each row are not significantly different (p≥0.05)
A-Unprocessed tamarind flour (control); B-Soaked tamarind flour; C-Roasted tamarind flour; D-Autoclaved tamarind flour
ΔEab colour interpretation: < 1 means not perceptible by the human eye, 1–2 means perceptible through close observation, 2–10 means perceptible at a glance, 11–49 means colours are perceptibly opposite, but still appear similar and 100 means colours are exact opposites.

Effect of processing methods on chemical composition of tamarind seed flours: The proximate composition and the total energy values of raw and processed tamarind seed flours are shown in Table 2.The protein content of the samples varied from 2.3 to 12.7%, respectively. The highest value was noted in sample A (12.7%) while sample D had the least value (2.3%). The protein value indicated for raw tamarind seed flour was however lower than the range of 18.4-26.9% reported by Caluw *et al*. (2010). It has been reported that tamarind seeds are better sources of protein when compared to other parts of the fruit since the seeds are nutrient reserve organs (Costa *et al*., 2015). The notable loss of protein due to soaking and autoclaving of tamarind seeds could be attributed to the leaching of soluble nitrogen into the processing medium. Similarly, the observed reduction in protein content of the roasted seeds may be attributed to denaturation. The result of this study corroborates the report on toasted fluted pumpkin seed flour (Fagbemi, 2007). It could be inferred from the results that the different temperature regime adopted during processing resulted in the gross depletion in protein content compared to the raw sample. Earlier report had indicated that the thermal stability of food proteins is markedly affected by the protein's environment, such as the amount of water associated with the protein (Dutson and Orcutt, 1984). Fat content of the flour samples ranged from 5.4 to 6.8%. The crude fat of the raw sample (6.4%) was within the range (5.6 to 10.9%) reported by Mlakar *et al.* (2009) though it differed significantly from the processed samples. Roasting of the seeds resulted in reduction in the fat content. Melting could occur which initiates the loss of volatile oil on open dry heat treatment (Mathur and Chaudhary, 2009). Similarly, moist heat treatment (autoclaving) decreased fat content possibly as a result of diffusion into the boiling water. In contrast, soaking of the seeds resulted in higher fat content compared with the control. The increase resulted probably as a result of the leaching of soluble components into the processing water accompanied with concentration of the fat in the seeds. Moisture contents of the samples ranged from 7.63-11.61%. Sample C had the least value (7.63%), followed by sample A (8.21%) and sample B (10.4%). Autoclaved seeds (sample D) had the highest moisture content. The moisture content of the seed flour samples was within the range of 11.4% to 22.7% reported by Gunasena and Huges (2000). Increase in moisture content was observed in processed tamarind seeds; however, an exception was in dry roasted seeds. This could be as a result of the high temperature the grains were subjected to during roasting process that led to the evaporation of moisture from the seeds. Moist processing (soaking) and moist heat processing (autoclaving) increased the moisture content of the flour, respectively due to the absorption of water during processing. Roasted tamarind seeds contained maximum dietary fibre (7.10%) followed by raw seeds (6.50%) and soaked seeds (6.51%) then autoclaved seeds (3.50%), respectively. The crude fibre content of unprocessed tamarind sample obtained in this study was however within the range of 6.0-7.0% earlier reported on some species (Oluseyi and Temitayo, 2015), but higher than the value of 2.33% reported by Marangoni *et al*. (1998). It is important to note that the crude fibre content of tamarind seed flour is much higher than that of major cereals like raw milled rice and wheat flour which contain 0.20% and 1.20% fibre, respectively as reported by Ahmed *et al*. (2013). There was no significant difference between raw and soaked tamarind seed flours. The high dietary fibre content of the roasted tamarind seed flour could be as a result of the effect of Millard reaction which may be analysed as lignin and thereby increase the apparent fibre content of the flour (Azizah and Zanion, 2009). Ash content of the samples ranged from 1.25 to 2.08%. Crude ash content of raw tamarind flour (1.66%) as reported in this study is lower than the range (2.5 to 4.4%) reported by Mlakar *et al* (2009). Soaking resulted in significant reduction of ash content due to the leaching out of both soluble macro and micro elements into the processing medium. In contrast, the ash content of autoclaved and roasted tamarind flour

was observed to be higher than the raw flour, respectively. This could be attributed to the inactivation of anti-nutritional factors inherent in the seeds by heat applied during processing. The carbohydrate content of unprocessed tamarind seed flour was found to be 64.6%. Siddhuraja *et al*. (1995) also recorded 61.70% carbohydrate in tamarind seeds compared to a range between 65.10 to 72.20% as reported by Gunasena and Huges (2000). However, the carbohydrate content of the flour samples was all significantly different from each other at p≤0.05. The autoclaved tamarind flour recorded the highest carbohydrate content (75.2%), followed by roasted sample (72.8%) and soaked sample (65.7%). The increase in the carbohydrate content of processed

tamarind seeds compared to the control is due to decrease in fat and protein contents of the samples. Generally, the carbohydrate content indicated in tamarind seed flours in this study established their suitability for industrial flour and starch production. Maximum energy value was found in raw tamarind seeds followed by roasted, soaked and then autoclaved seeds with mean value of 366.37, 363.85, 361.38 and 358.33 kCal per 100g, respectively. The energy levels reported in processed flour samples compared to the control could be as a result of their lower fat content. However, it is imperative to note that the raw and processed tamarind seed flour had energy values higher than rice (345 kCal/100g) and wheat (341 kCal/100g) as indicated by Gopalan *et al*. (2010).

Table 2: Proximate composition of tamarind seed flour (%)

Samples	Moisture	Protein	Ash	Fat	Fibre	Carbohydrate	Energy (kCal/100g)
A	8.21[ab]±0.02	12.66[d]±0.04	1.66[ab]±0.01	6.37[b]±0.02	6.50[b]±0.02	64.60[a] ±0.05	366.37[bc]±0.05
B	10.42[c]±0.03	9.34[c] ±0.03	1.25[a]±0.01	6.82[bc]±0.02	6.51[b]±0.02	65.66[ab] ±0.03	361.38[b]±0.12
C	7.63[a] ±0.02	4.26[b] ±0.02	2.05[c]±0.01	6.17[b]±0.02	7.10[bc]±0.03	72.82[c] ±0.02	363.85[b]±0.09
D	11.61[d]±0.02	2.26[a] ±0.02	2.08[c]±0.01	5.41[a]±0.02	3.50[a]±0.01	75.15[cd] ±0.02	358.33[a]±0.11

Mean± standard deviation of triplicate determination
Key a-d: Means with the same superscripts within each row are not significantly different (p≥0.05)
A-Unprocessed tamarind flour (control); B-Soaked tamarind flour; C-Roasted tamarind flour; D-Autoclaved tamarind flour

Selected mineral elements of tamarind seed flours are presented in Table 3. The result indicated that raw tamarind seed flour is rich in potassium 487.37mg/100g, and magnesium 136.78mg/100g but have lower values of iron 22.34/100g and calcium 11.72mg/100g, respectively. However, there exists variation in the elemental concentrations in the processed samples although soaked and autoclaved samples had significantly lower mineral concentrations than roasted seeds. The observed low concentration of magnesium in soaked and autoclaved sample respectively could be due to dilution effect during their preparation compared to the roasted sample. Comparatively, it has been observed that moist heat techniques decreased the mineral content

more than the dry heat method probably as a result of leaching of minerals into the decanted processing medium. Potassium concentration in the tamarind seed flour was maximum among all the elements determined which corroborates earlier report by Akajiaku *et al*. (2014). The range of calcium concentration in raw and processed tamarind seed flour was 11.72-18.76 mg per 100 g, which falls within the range of 9.30 to 78.60mg per 100 g recorded by Gunasena and Huges (2000). The iron content of raw and processed tamarind seed flour was in a range of 22.34 to 31.04 mg per 100g. However, Ajayi *et al*. (2006) reported much higher iron concentration (45.50 mg per 100g) in the tamarind seeds.

Table 3: Mineral composition of tamarind seed flour (mg/100g)

Samples	Calcium	Magnesium	Potassium	Iron
A	11.72[a]±0.02	136.78[c]±0.05	487.37[c]±0.13	22.34[a] ±0.02
B	18.38[c]±0.04	125.49[a]±0.03	293.66[b]±0.06	23.84[b] ±0.03
C	14.08[b]±0.05	152.55[d]±0.07	586.34[d]±0.09	31.04[d]±0.07
D	18.76[c]±0.03	132.62[b]±0.02	224.45[a]±0.05	25.84[bc]±0.05

Mean± standard deviation of triplicate determination
Key a-d: Means with the same superscripts within each row are not significantly different (p≥0.05)
A-Unprocessed tamarind flour (control); B-Soaked tamarind flour; C-Roasted tamarind flour; D-Autoclaved tamarind flour

The effect of processing methods on anti-nutrient composition of tamarind seed flours is presented in Table 4. The alkaloid concentration ranged from 2.03-2.57mg/100g. It could be inferred that the alkaloid content was highest in the control sample. Soaked and autoclaved tamarind samples had lower alkaloid content than the control; the decrease in alkaloid

content may be as a result of leaching into the processing water. However, roasted sample had lowest alkaloid content among the flour samples probably as a result of the dry heat applied. The trypsin inhibitor concentration content ranged from 384.16mg -742.07mg/100g with sample D having the highest content (782.0mg/100g), while sample A had the least

value (384.16mg/100g). Low amounts of proteins of the crude protein extract of treated seeds (soaked, autoclaved or roasted) exhibited higher inhibitory activity against trypsin, compared to the control. It had been reported that some proteins contain high concentrations of trypsin inhibitor, hence increasing the level of such protein in the diet will increase the incidence of pancreatic pathology, while for proteins with quite low levels of trypsin inhibitor, increasing the protein in the diet above 10% will have a protective effect (Gumbman *et al*., 1986). The phytate content of the raw tamarind grain was 2.36mg/100g. However, all the adopted processing techniques reduced the phytate content in the tamarind seeds. The reduction in phytate content after soaking or autoclaving of the seeds could be attributed to the leaching into the processing water. Similarly, roasting significantly ($p \leq 0.05$) reduced the phytate content of processed

tamarind seeds. The oxalate content of the samples ranged from 5.74mg/100g to 6.24mg/100g. Soaked and autoclaved tamarind samples had higher oxalate content than the control. The reason for the higher oxalate recorded in these samples could be explained by the fact that small fraction of hulls were still attached to the dehulled seeds after treatment. However, roasted sample had lower oxalate content than the control solely because clean dehulled seeds were obtained after roasting; leaving no trace of the oxalate containing brownish hull. It is quite imperative to note that thermal processing of seeds has been acknowledged to be very effective in enhancing the nutritional value and reducing anti-nutrient factors, however, these processes are affected by many and varied factors especially the influence of temperature-time combinations with respect to the reduction of inherent anti-nutrient factors.

Table 4: Anti-nutrient composition of tamarind seed flours

Samples	Alkaloids (%)	Oxalate (mg/100g)	Phytate (mg/100g)	Trypsin inhibitor (mg/100g)
A	2.57[b]±0.02	6.13[b] ±0.02	2.36[ab] ±0.02	384.16[a] ±0.05
B	2.39[ab] ±0.01	6.24[b] ±0.03	2.18[a] ±0.01	664.23[c] ±0.05
C	2.03[a] ±0.01	5.74[a] ±0.01	2.21[a] ±0.01	420.61[b] ±0.06
D	2.14[a] ±0.01	6.19[b] ±0.01	2.27[ab] ±0.02	742.07[d] ±0.11

Mean± standard deviation of triplicate determination
Key a-c: Means with the same superscripts within each row are not significantly different ($p \geq 0.05$)
A-Unprocessed tamarind flour (control); B-Soaked tamarind flour; C-Roasted tamarind flour; D-Autoclaved tamarind flour

Effect of processing methods on pasting properties of tamarind seed flours: There were significant ($p \leq 0.05$) differences in the pasting profile of the flour samples as shown in Table 5. The results indicated that soaked, autoclaved and roasted flour samples had distinct pasting properties compared to the control sample. Peak viscosity (PV) of the flour samples ranged from 248.28 to 472.26 RVU. The soaked tamarind flour (sample B) had the highest value (472.20 RVU) among the processed flours. The significant variation noted in the raw and processed flour samples explains the nature and composition of their starches. It could be inferred from the result that soaked tamarind flour would exhibit higher gel strength and gel forming potential during cooking than other processed flours. Such flour could find application in food preparations that require high thickening power at high temperatures; other flour samples also possess varying high peak viscosities that could be useful in food formulations. Trough viscosity ranged from 203.33-416.72 RVU. Sample B had the highest value while sample C had the least value. The trough viscosity is the ability of starch granules to remain undisrupted when the flour paste is subjected to a hold period of constant high temperature (95°C for 2.5 min.) and mechanical shear stress as reported by Bakare (2008). Breakdown viscosity ranged from 16.86 to 97.97 RVU. The control (sample A) had the highest value

compared with other flour samples. This pasting attribute measures the tendency of the swollen starch granules to rupture when held at high temperatures and continuous stirring and an indicative of paste stability (Akanbi *et al*., 2009). Hence, the highest breakdown viscosity noted in the control sample indicated lower ability of such flour to withstand heating and shear stress during cooking compared to soaked, roasted and autoclaved flour samples. Final viscosity of the raw and processed tamarind flour samples ranged from 757.39 to 1218.80 RVU. Soaked tamarind flour sample had the highest value while roasted flour had the least. Final viscosity reflects the potential of flour dispersions to form viscous pastes on cooling. Setback viscosity of raw and processed flours varied between 554.06 and 802.09 RVU. Sample B had the highest value while sample C had the least value. Flour with low setback viscosity may possess low amylase value with high molecular weight (Peroni *et al*., 2006), while flour with high setback value exhibit lower retrogradation of starch paste as reported by Ikegwu *et al*. (2010). Hence, the high setback viscosity of soaked tamarind flour is an indication of less tendency to retrograde compared to autoclaved and roasted samples as well as the control sample. The pasting temperature of the flour samples ranged from 68.23-83.70°C. The pasting temperature is a measure of the minimum temperature required to cook flour starch

beyond its gelatinization point (Adebowale *et al.*, 2008). Gelatinization is an irreversible process that occurs when starch/starch-based foods are heated in water beyond a critical temperature. High pasting temperature values indicate the ability of the flour starch dispersion to resist swelling and rupturing that might be due to size of the granules and effect of the processing methods.

Table 5. Pasting properties of tamarind seed flours

Sample	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown Viscosity (RVU)	Final Viscosity (RVU)	Setback Viscosity (RVU)	Peak Time (Min)	Pasting Temp.(°C)
A	343.81[b]±20.67	272.86[b]±15.53	97.97[b]±5.14	917.69[b]±71.55	644.84[b]±56.00	4.82[b]±0.04	83.70[b]±0.77
B	472.20[b]±10.87	416.72[b]±2.64	55.47[b]±13.52	1218.80[b]±16.26	802.09[b]±18.90	6.04[b]±0.15	82.58[b]±0.98
C	248.28[b]±0.68	203.33[b]±1.73	44.94[b]±2.40	757.39[b]±7.99	554.06[b]±19.72	6.95[b]±0.04	67.72[b]±0.14
D	340.84[b]±4.91	329.39[b]±7.11	16.86[b]±2.21	974.22[b]±21.13	666.91[b]±14.97	5.98[b]±0.04	68.23[b]±0.46

Mean± standard deviation of triplicate determination
Key a-c: Means with the same superscripts within each row are not significantly different (p≥0.05)
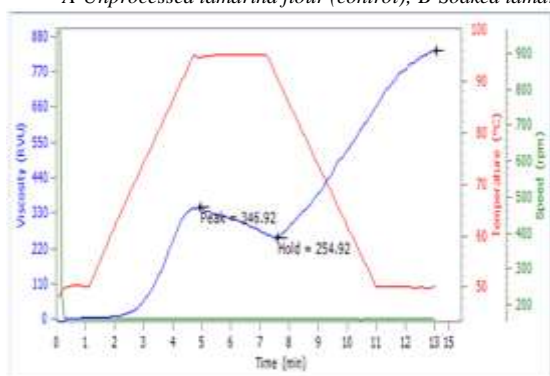*A-Unprocessed tamarind flour (control); B-Soaked tamarind flour; C-Roasted tamarind flour; D-Autoclaved tamarind flour*

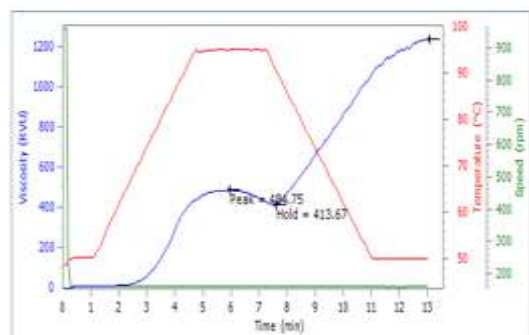**Fig 2**: Influence of heating time on the viscosity of sample A (control)

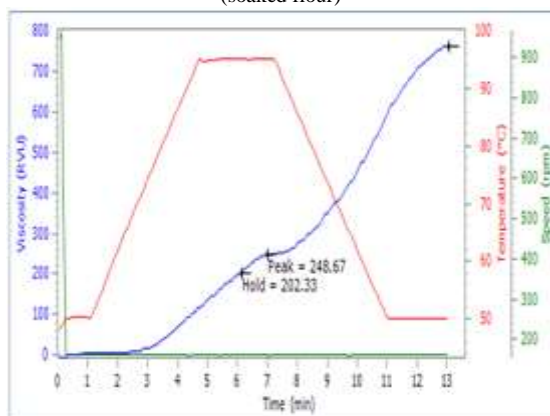**Fig 3**: Influence of heating time on the viscosity of sample B (soaked flour)

Fig 4: Influence of heating time on the viscosity of sample C (roasted flour)
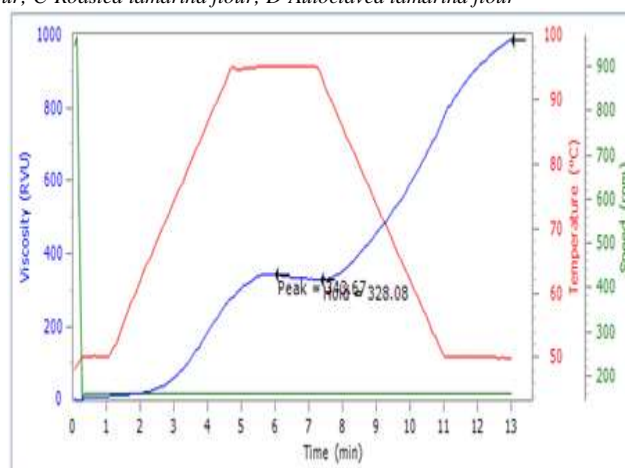

Fig 5: Influence of heating time on the viscosity of sample D (autoclaved flour)

Generally, the pasting temperature of the raw and processed tamarind seed flours were lower than boiling temperature of water (100°C); hence such flours are expected to form paste before boiling point of water within a peak time range of 4.8 to 7.0 min as indicated in Table 5.

Conclusion: This study establishes that the intrinsic value of raw tamarind seed could be enhanced through processing conditions such as soaking, autoclaving and roasting. The roasting process was observed to be the most effective in reducing various anti-nutritional components and maintaining essential nutrients of tamarind seeds. It is evident that tamarind seed flour has a huge potential to be explored in African tropics due to over dependence on conventional protein source, as well as the recurring incentive to use available food residues.

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