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COMPARISONS OF SOME FUNCTIONAL AND PASTING PROPERTIES OF TIGER NUT (Cyperus esculentus) FLOURS PRODUCED UNDER DIFFERENT PROCESSING CONDITIONS

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Cyperus esculentus is an underutilized and readily available crop. Successful utilization of its flour for food products will depend on its functional and pasting characteristics which are usually affected by different processing conditions. The objective of this study therefore was to determine and compare the extent to which the different processing conditions will affect these properties of tiger nut flours. Fresh and dry yellow tiger nuts were purchased from Ojo market in Ibadan, Nigeria. They were cleaned, sorted, washed and separated into four major batches for both the fresh and dry samples. These were subjected to different processing conditions of fermentation, germination and roasting. The untreated fresh and dry samples were used as controls. Flours were produced from the samples using standard procedures. The functional and pasting characteristics of the samples were evaluated. Water absorption capacity increased to 2.70 and 2.20 g/g for fresh roasted and dry fermented samples respectively. Oil absorption capacity increased to 1.40 g/g for the dry germinated sample and 1.35 g/g for dry fermented, dry roasted and fresh fermented samples. There were increases in swelling power with germination, fermentation and roasting. Peak viscosity increased from 710 to 779 RVU and breakdown from 6 to 14 RVU while setback decreased from about 90 to about 10 RVU with all processing methods. Final viscosity was generally not affected by all processing methods. The results of the pasting temperatures and peak time combinations indicated that the dry germinated sample will be easier to cook than all other samples.

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I INTRODUCTION

The cultivation and utilization of tiger nut tubers is a practice known to have started with the Egyptians at about 5000 BC.[1, 2] Tigernut (Cyperus esculentus) is an underutilized crop of the family Cyperaceae which produces rhizomes from the base and tubers that are somewhat spherical. Three varieties of tiger nut tubers exist namely yellow, brown and black varieties. The black variety is not common in Nigeria but the tubers are mainly available in Ghana.[3] The other two varieties of tiger nut tubers are commonly sold in local markets across many states in Nigeria. Generally, the yellow variety tiger nut tuber is preferable than the brown variety tiger nut tuber.[4] Tigernut (Cyperus esculentus) is an underutilized, inexpensive and readily available crop in Nigeria. The tubers contain significant amount of protein, fat, minerals and vitamins.[5, 6] Tiger nut tubers contain digestive enzymes like catalase, lipase and amylase which assist to in the breakdown of macromolecules such as protein, fat and carbohydrate to simpler substances during fermentation and germination. Roasting is another processing technique that can also influence the functionality and pasting characteristics of flours. Tiger nut is known to contain some anti-nutritional factors such as tannin, phytate, saponin and alkaloids. These anti-nutrients can also be increased or decreased during processing. Mineral contents of flours are usually affected by processing techniques like fermentation, germination, and roasting. The various modifications that take place in food products in processing can affect the functionality and pasting behavior either positively or negatively. Fermentation and germination are food processing techniques in which the quality of cereal, legume, or tuber can be improved upon for both digestibility and physiological function, especially through the breakdown of certain anti-nutrients, such as phytate, tannin, and protease inhibitors.[7] During fermentation and germination, enzymatic activities and the production of bioactive compounds are increased within the seed.[8, 9] Germination was also reported to influence the increase in vitamin concentration and bio-availability of trace elements and minerals.[10] Functional properties are the properties, which define the consumers' acceptability of products made from such food ingredients. These are the characteristics that define how suitable a food ingredient will be for the intended purpose. The utilization of food ingredients in the production of final food products depends on various functional properties.[11] Therefore, the objective of this study was to determine the effect of fermentation, germination and roasting processing techniques on the functionality and pasting characteristics of tiger nut flours.

II MATERIALS AND METHODS

Materials

Yellow variety tiger nuts were purchased from a local merchant at Ojo market in Ibadan.

Methods

Germination and production of tiger nut flour.

A modified method of Ade-Omowaye *et al.*[12] was used for germination of tiger nut tubers. The tubers (1 kg) were manually sorted, cleaned, and soaked in 3 L of water at room temperature (30±2^{0}C) for 16 hr. The nuts were then washed and kept in a clean container, covered with a piece of cheesecloth to allow passage of oxygen for the germinating tubers. The tubers were then allowed to germinate for 72 hr. at 37^{0}C with frequent watering. The sprouts were then rinsed with tap water and dried in a cabinet drier at 75^{0}C for 8 hrs. The dried germinated tubers were milled in an attrition mill through a 210μm sieve to obtain a fine powder. The flour was packaged in high-density polyethylene and placed in a covered plastic bucket and kept in a deep freezer (-10^{0}C) until required for further use.

Production of fermented tiger nut flour

A modified method of Adejuyitan *et al.*[13] was utilized in the production of fermented tiger nut flour. The tiger nut tubers were sorted, cleaned, washed, and soaked in water, and left to undergo natural fermentation for 48 hrs. The fermented tubers were drained and dried in a cabinet drier at 75^0C for 8 hrs. The dried tubers were milled in an attrition mill. The flour was packaged in high-density polyethylene and placed in a covered plastic bucket and kept in a deep freezer (-10^0C) until required for further use.

Roasting and production of tiger nut flour

A modified method of Oladunmoye *et al.*[14] was used in the production of roasted tiger nut flour. The tiger nut tubers (1 kg) were sorted, cleaned, and washed. The tubers were dried at 75^0C for 8 hrs and pan-roasted on a controlled gas stove, the non-luminous flame for 30 min. The roasted tubers were allowed to cool and then milled in an attrition mill. The flour was packaged in high-density polyethylene and placed in a covered plastic bucket and kept in a deep freezer (-10^0C) until required for further use.

Determination of functional properties

Bulk density (BD)

The bulk density of samples was determined using the method described by Wang and Kinsella[15] Ten grams (10g) of the sample was weighed into a 50 ml graduated measuring cylinder. The sample was packed by gently tapping the cylinder on the benchtop. The volume of the sample in the cylinder was then recorded. Measurements were carried out in triplicates.

$$\text{Bulk density (g/ml)} = \frac{\text{weight of sample}}{\text{volume of sample after tapping}} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Water absorption capacity (WAC)/ Oil absorption capacity (OAC)

Water and oil absorption capacities of the flour samples were determined using the method of Beuchat.[16] One gram (1g) of the flour sample was mixed with 10 ml of water or oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2°C) for 30 minutes. The suspension was then centrifuged at 2000 rpm for 30 minutes. The volume of water or oil in the sediment-water was measured. Water and oil absorption capacities were calculated as ml of water or oil absorbed per gram of flour.

Swelling power

The swelling power was determined using the method described by Takashi and Sieb.[17] One gram (1g) of flour was weighed into a 25 ml centrifuge tube. Ten (10) ml of distilled water was added and mixed gently. The slurry was heated in a water bath at 60^0C, 70^0C, 80^0C, 90^0C, and 100^0C respectively for 15 minutes. During the heating process, the slurry was stirred gently to prevent the clumping of the flour. On completion, the tube containing the paste was centrifuged at 3000 rpm for 10 minutes. The supernatant was decanted immediately after centrifuging. The weight of the sediment was taken and recorded.

$$\text{Swelling power (\%)} = \frac{\text{weight of the wet mass of flour}}{\text{weight of dry sample}} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Determination of pasting properties

The pasting profiles of the flours were studied using a Rapid Visco-Analyzer (RVA) of Newport Scientific Pty. Ltd, Warriewood, Australia (perten Instrument), Model RVA Super 4 at the Multidisciplinary Laboratory, University of Ibadan, using the thermocline for windows version 1.1 software (1998). Rapid

Visco Analyzer was connected to the PC where the pasting characteristics and RVU curves were directly recorded.

III RESULTS

Effect of processing conditions on functional properties of tiger nut flour

The bulk density, water absorption capacity, and oil absorption capacity of samples are presented in Table 1.

Table 1. Effect of processing conditions on functional properties of tiger nut flour

Sample	Bulk density	WAC (g/g)	OAC (g/g)
FRT	0.90^{a}	2.70 ± 0.14^{a}	1.60 ± 0.14^{a}
FFT	0.74^{cd}	1.85 ± 0.07^{c}	1.35 ± 0.07^{b}
DGT	0.76^{cd}	2.05 ± 0.07^{bc}	1.40 ± 0.00^{ab}
DFT	0.77^{bc}	2.20 ± 0.00^{b}	1.35 ± 0.07^{b}
DUT	0.78^{bc}	2.15 ± 0.21^{bc}	1.30 ± 0.14^{b}
DRT	0.72^{d}	1.90 ± 0.14^{bc}	1.35 ± 0.07^{b}
FUT	0.78^{b}	2.10 ± 0.14^{bc}	1.60 ± 0.14
FGT	0.88^{a}	2.10 ± 0.14^{bc}	1.60 ± 0.00^{a}

Means having the same superscript along the same column are not significantly different ($p\leq0.05$).
FRT = Fresh Roasted Tiger nut flour, FFT = Fresh Fermented Tiger nut flour, DGT = Dried Germinated Tiger nut flour, DFT = Dried Fermented Tiger nut flour, DUT = Dried Untreated Tiger nut flour, DRT = Dried Roasted Tiger nut flour, FUT = Fresh Untreated Tiger nut flour, FGT = Fresh Germinated Tiger nut flour

Effect of temperature on the swelling capacity of tiger nut flour

The results of the swelling capacity of tiger nut flour at different temperatures are presented in Table 2.

Table 2. Effect of processing conditions on the functional property (swelling power) in (ml/g).

Sample	**60^{0}C**	**70^{0}C**	**80^{0}C**	**90^{0}C**	**100^{0}C**
FRT	2.75 ± 0.07^{a}	3.05 ± 0.07^{a}	3.25 ± 0.21^{d}	3.80 ± 0.14^{d}	4.40 ± 0.00^{f}
FFT	2.05 ± 0.21^{b}	3.00 ± 0.14^{ab}	3.70 ± 0.14^{bcd}	4.55 ± 0.07^{bc}	5.65 ± 0.07^{c}
DGT	2.05 ± 0.07^{b}	2.60 ± 0.14^{c}	5.30 ± 0.57^{a}	6.25 ± 0.35^{a}	7.30 ± 0.14^{a}
DFT	1.90 ± 0.00^{b}	2.95 ± 0.07^{ab}	3.90 ± 0.14^{bc}	4.85 ± 0.07^{b}	5.95 ± 0.07^{b}
DUT	1.90 ± 0.14^{b}	2.65 ± 0.07^{c}	3.30 ± 0.28^{cd}	4.85 ± 0.07^{b}	5.65 ± 0.07^{c}
DRT	2.10 ± 0.00^{b}	2.80 ± 0.00^{bc}	3.85 ± 0.07^{bcd}	4.60 ± 0.14^{bc}	5.55 ± 0.07^{c}
FUT	2.10 ± 0.28^{b}	3.00 ± 0.00^{ab}	3.70 ± 0.00^{bcd}	4.35 ± 0.07^{c}	5.05 ± 0.07^{e}
FGT	2.20 ± 0.00^{b}	3.15 ± 0.07^{a}	3.95 ± 0.07^{b}	4.85 ± 0.07^{b}	5.35 ± 0.07^{d}

Means having the same superscript along the same column are not significantly different ($p\leq0.05$).
FRT = Fresh Roasted Tiger nut flour, FFT = Fresh Fermented Tiger nut flour, DGT = Dried Germinated Tiger nut flour, DFT = Dried Fermented Tiger nut flour, DUT = Dried Untreated Tiger nut flour, DRT = Dried Roasted Tiger nut flour, FUT = Fresh Untreated Tiger nut flour, FGT = Fresh Germinated Tiger nut flour

Effect of processing conditions on pasting properties of tiger nut flour

The results of the effect of processing conditions on the pasting of tiger nut flour are presented in Table 3.

Table 3. Effect of processing conditions on pasting properties of tiger nut flour (RVU).

Sample	Peak viscosity	Trough	Breakdown	Final viscosity	Setback	Peak time	Pasting temperature
FRT	611.50±0.71^{c}	609.00±1.41^{c}	2.50±0.71^{d}	619.00±1.41^{c}	10.00±0.00^{c}	6.10^{a}	81.96±9.35^{c}
FFT	779.50±0.88^{a}	765.50±8.56^{a}	14.00±2.83^{ab}	686.00±14.10^{a}	102.50±5.54^{a}	4.84^{c}	89.95±7.35^{a}
DGT	718.50±2.12^{ab}	698.50±3.54^{ab}	20.00±1.41^{a}	758.00±7.07^{ab}	59.50±2.50^{ab}	4.43^{c}	80.99±6.56^{c}
DFT	726.00±1.41^{ab}	715.50±0.71^{ab}	10.50±0.71^{bc}	782.50±0.71^{ab}	67.00±0.00^{ab}	5.17^{bc}	85.95±7.80^{ab}
DUT	710.00±2.83^{ab}	708.50±2.12^{ab}	1.50±0.71^{d}	795.00±2.83^{ab}	86.50±0.50^{a}	6.20^{a}	82.75±9.25^{bc}
DRT	672.00±2.83^{bc}	669.00±0.00^{bc}	1.00±0.00^{d}	705.00±0.00^{bc}	36.00±0.00^{bc}	5.83^{ab}	83.86±8.45^{b}
FUT	712.50±2.12^{ab}	706.50±2.12^{ab}	6.00±0.00^{cd}	796.50±7.78^{ab}	90.00±5.66^{a}	5.94^{ab}	88.94±6.55^{a}
FGT	737.50±4.95^{ab}	723.50±3.54^{ab}	9.00±8.49^{d}	779.00±3.00^{ab}	59.00±3.00^{ab}	4.77^{c}	85.89±9.35^{ab}

This means having the same superscript along the same column are not significantly different ($p \leq 0.05$).

FRT = Fresh Roasted Tiger nut flour, FFT = Fresh Fermented Tiger nut flour, DGT = Dried Germinated Tiger nut flour, DFT = Dried Fermented Tiger nut flour, DUT = Dried Untreated Tiger nut flour, DRT = Dried Roasted Tiger nut flour, FUT = Fresh Untreated Tiger nut flour, FGT = Fresh Germinated Tiger nut flour

IV DISCUSSION

The bulk density ranged between 0.72 and 0.90. The freshly roasted sample (FRT) had the highest bulk density while dry roasted had the lowest. There was no significant difference between the densities for fresh roasted (FRT) and fresh germinated (FGT) samples but their densities were significantly different (($p \leq 0.05$) from all other samples. The values obtained in this experiment were slightly lower than 0.83 – 0.91 reported by Adejuyitan *et al.*[13] for fermented tiger nut flours. Mengistu *et al.*[18] reported the values of 0.86 and 0.90 for fermented sorghum and maize respectively. Bello *et al.*[19] reported bulk density of 0.66 for fermented sorghum flour. This study has shown that germination and roasting resulted in a significant increase in bulk density. Bulk density is used as a measure of sinkability and ability to disperse during mixing operations. The values of bulk density obtained in this study imply that samples FRT and FGT have higher sinkability and will readily disperse during the mixing operation.

The water absorption capacities (WAC) ranged from 1.85 to 2.70g/g. The WAC for freshly roasted tiger nut (FRT) is significantly ($p \leq 0.05$) higher than all other samples while the fresh fermented (FFT) sample had the lowest value which is not significantly different from all other samples. The water absorption capacities obtained in this study are higher than 1.70g/g reported by Eke and Akobundu[20] for African yam beams. Mengistu *et al.*[18] reported values of 2.44 and 2.15g/g for fermented sorghum and maize respectively while Olapade *et al.*[21] reported values of 1.50 and 1.80 for plantain and cowpea respectively. Bello *et al.*[19] reported 1.30g/g for fermented sorghum flour while Odoemelam[22] reported 3.40 ml/g for conophor flour. High water absorption capacity is utilized as an indication of a loose association of the starch polymer in the native granules. It is reflective of protein-water interaction in food systems and is therefore influenced greatly by protein content.[23]

The oil absorption capacity (OAC) ranged between 1.30 and 1.60g/g. There was no significant difference between FUT, FRT and FGT samples but their values are significantly higher than all other samples. Samples FFT, DGT, DFT, DRT and DUT are significantly lower in oil absorption capacity than FUT, FRT and FGT. This implies that oil absorption capacity decreases for fresh fermented, dry fermented, dry germinated, and dry roasted samples. Bello *et al.*[19] reported a value of 1.80 for fermented sorghum flour.

The swelling power at 60^0C ranged between 1.90 – 2.75 ml/g. The swelling power of sample FRT is significantly ($p \leq 0.05$) higher than the values for every other sample. There are no significant differences among other samples.

At 70^0C the swelling power ranged from 2.60 to 3.16 ml/g among which sample FGT had the highest and sample DGT had the lowest value. There are no significant differences ($p \leq 0.05$) between samples FRT, FFT, FUT, DFT, and FGT. But their values are significantly different ($p \leq 0.05$) from those of samples DUT, DGT and DRT.

At 80^0C swelling power ranged from 3.25 – 5.30 ml/g. The value for sample DGT is significantly ($p \leq 0.05$) higher than all other samples. At 90^0C swelling power ranged between 3.80 – 6.25 ml/g. Again the value for sample DGT was found to be significantly higher than the values of all other samples while the value for sample FRT was found to be significantly lower than the values of all other samples. At 100^0C swelling power ranged between 4.40 and 7.30 ml/g. The value for sample DGT was also found to be significantly higher than the values of all other samples while the value for sample FRT was significantly lower than the values for all other sample.

The trend exhibited in this study showed that the swelling power of tiger nut flours increases with an increase in temperature. At temperatures of 80^0C and above sample DGT had the highest swelling power while sample FRT had the lowest value. Obomeghei[24] reported the values of 1.53, 2.37, 2.63, 2.73 and 4.77 % for unfermented pigeon pea, soybean, red bambara groundnut, white bambara groundnut, and okra seed flours respectively. Obomeghei[24] also reported a range of 1.20 – 1.70 for unfermented samples of four types of sweet potato flours. Swelling power has been classified as a measure of the hydration capacity of starches and is utilized to provide evidence for associative binding forces within starch granules.[23]

Effect of processing conditions on pasting properties of tiger nut flour

The peak viscosity of the flour samples ranged between 611.50 and 779.50 RVU. The values for samples FFT, DGT, DFT, DUT, FUT, and FGT are not significantly different from one another but are significantly ($p \leq 0.05$) higher than the values for samples FRT and DRT. The peak viscosity has been described as the highest viscosity value attained in a heating cycle and a measure of the ability to form pastes. The values obtained in this study are less than the value 1,492±27 RVU reported for wheat flour[25] but higher than 162.10±0.35 RVU reported in another study for wheat flour[26] but Ekunseitan *et al.*[27] reported a value of 93.77±0.70 for wheat flour in another experiment. The values of 95.64±0.06 and 90.83±0.08 RVU were reported for red Bambara groundnut and pigeon pea flours respectively. [24] The value for peak viscosity obtained in this experiment is far higher than the value 255.64±1.73 RVU reported for flour from maize stored at 35°C for 12 months. [28]

The breakdown viscosity ranged from 1.00 to 20.00 RVU. Sample DGT had the highest value of breakdown viscosity followed by sample FFT. The values for DGT and FFT are significantly ($p \leq 0.05$) higher than the values for all other samples. The breakdown viscosity of cooked pastes is used to measure their stability to shearing during cooking.[29] The values for breakdown viscosity obtained in this study are similar to 11.63±0.07 and 3.71±0.06 RVU reported for red Bambara groundnut and pigeon pea respectively[24] and

5.31±0.71 RVU reported for maize flour.[28] Ekunseitan et al.[27] reported a value of 31.97±1.93 RVU for wheat flour.

The final viscosity ranged between 619.00 and 796.50 RVU. The value for the final viscosity of sample FRT is significantly ($p \leq 0.05$) lower than the values for all other samples. The significant difference does not exist among all other samples. The higher the final viscosity, the higher is the ability to form firm gel or viscous pastes. It is an index used in predicting the texture of food products. The values obtained in this study are far higher than the values 221.33±0.05, 127.43±0.04, 255.64±1.73, and 219.90±1.15 RVU reported for red Bambara groundnut, pigeon pea[24] maize[28] and wheat[26] respectively.

The setback viscosity was found to range from 10.00 to 102.50 RVU. The setback value for sample FFT was highest while the value for sample FRT was lowest. The value for sample FRT was significantly ($p \leq 0.05$) lower than the values for all other samples. A high setback value is used to indicate a higher tendency to undergo retrogradation after heating and cooling of pastes. This implies that sample FRT has the least tendency to undergo retrogradation while sample FFT will retrograde faster. The values of 137.32±0.05, 40.31±0.03, 405.92±2.46, 124.90±1.15, 71.16±4.94, 931±5.00 RVU were reported for red Bambara groundnut, pigeon pea[24] maize[28] and wheat[26,27,25] respectively.

The pasting times ranged from 4.43 to 6.20 min with DUT having the highest peak time and DGT having the least. There were significant differences ($p \leq 0.05$) between the pasting times. The values for samples FRT, DRT, FUT, and DUT are not significantly different from each other but their values are significantly ($p \leq 0.05$) higher than the values for samples FFT, DGT and FGT. The values obtained in this study are within the ranges reported for Bambara groundnut, pigeon pea, maize and wheat flours

The pasting temperatures vary from 80 to 90^{0}C. There are no significant differences ($p \leq 0.05$) among samples FFT, FUT, and FGT in terms of pasting temperatures. Their values are significantly higher than the values for all other samples. Sample DGT had the lowest pasting temperature. This implies that the dry germinated sample (DGT) will be expected to start gelatinization at about 80^{0}C whereas the fresh untreated sample FUT will start gelatinization at about 90^{0}C. The results also indicate that the dry germinated sample (DGT) will be easier to cook than all other samples. The values obtained in this experiment are higher than those reported for maize[28] but lower than those reported for the wheat[25,26,27] and similar to those reported for Bambara and pigeon pea flours.[24]

V CONCLUSION

Fermentation, germination and roasting increased the bulk densities except in dry roasting. These processing operations had no significant influence on water absorption capacity and oil absorption capacity. Generally, the swelling power of tiger nut flours increased with an increase in heating temperature during processing and at 80^{o}C temperature or more the dry germinated tiger nut flour had the highest swelling power. Peak viscosity is increased during fermentation, germination and roasting generally except in fresh roasting. Setback viscosity is also reduced with all processing methods except in fresh fermentation.

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