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Effect of yam specie and steaming methods on pasting properties of pre-gelatinized flour and sensory attributes of dough

Akinwande, B.A[1,*], Abiodun, O.A[2] and Adeyemi, I.A[1]

[1]Department of Food Science and Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

[2]Food Science and Technology Department, Osun State Polythechnic, Iree, Osun State, Nigeria.

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ABSTRACT

Instant yam (pre-gelatinized) flour was made from different yam species by varying steaming methods and time. Diced cubes were steamed in autoclave for 5 min and Barlet steamer at for 10, 20 and 30 min. Raw and pre-gelatinized cubes were dried and milled. Pasting properties of flour and sensory analysis of reconstituted dough were determined. Pasting properties of samples steamed for 5 min in autoclave were close to those steamed for 20 min in Barlet steamer, which were not significantly (p<0.05) different from those steamed for 30 min. Pre-gelatinized *D. dumetorum* flour could serve as thickening agent in instant food products. Its cultivation should be encouraged for industrial application.

Introduction

In Nigeria, yams are processed into various food forms, which include pounded yam (from *D. rotundata*, and sometimes *D. cayenensis*), boiled yam, roasted or grilled yam, fried yam slices and yam balls, mashed yam, yam chips and flakes. Fresh tubers are also made into flour, which is cooked in boiling water and turned into a thick paste and eaten with soup. Some species of yams in Nigeria are suitable for pounding or mashing after cooking while others are not.

Of all the *Dioscorea* species, *D. rotundata* (white yam) is the most important in West Africa. It is the most widely cultivated in the belt of Nigeria because of its economic value and uses while most of the other species are lesser-known yams, e.g. *D. dumetorum* and *D. alata*, and are underutilized. According to Alves *et al*. (2002), yam starch has desirable properties like low pH and viscosity stability at high temperatures. However, the native starch retrogrades after heat treatment and this is of disadvantage when applied to food systems. Pre-gelatinized yam flours are made by subjecting the tuber to heat treatment (Ekwu *et al.*, 2005). Application of heat to starchy foods in the presence of water improves the texture and digestibility (Adebowale *et al*., 2005). At 25 ºC, pre-gelatinized starch can increase the viscosity of water and are thus useful as thickening agent in instant food products (Majzoobi, *et al*., 2011).

In Nigeria, there are certain ethnic groups that relish consumption pounded yam and 'poundo' yam, which also serve as important sources of carbohydrate. Research has been carried out on processing of pre-gelatinized yam flour (Iwuoha, 2004; Ekwu *et al*., 2005; Iwuoha and Nnanemere, 2003) but more research work needs to be conducted on underutilized species of yam to ascertain their usefulness in various areas. *D. dumentorum* that is underutilized has high crude protein content of 7.0-11.37 (g/110g) (Alozie *et al*., 2009). Processing fresh crop to flour has the advantage of being able to keep well and with ease of marketing at great distances.

In view of the above, there is need to study different species of yam, especially the underutilized ones, for the production of raw and pre-gelatinized yam flour. The research also looked into effect of steaming method and time on the properties of pre-gelatinized flour and its reconstituted dough. This will enable the food processor to make use of different species of yam and the information on the processing method/time will serve as a guide for flour processing..

Materials and Methods

Four species of yam, *D. dumetorum* (var. 'esuru'), *D. cayenensis* (var. 'olo'), *D. alata* (var. TDa 291) and *D. rotundata* (var. 'efuru') that were used for this study were purchased from a local market in Ilesha, Nigeria.

Preparation of raw flour

Yam tubers were washed, drained and peeled. The peeled tubers were diced (2 cm^3) and put in 800 ppm sodium metabisulphite solution for 20 min. Yam dices were dried in a cabinet drier (Hotbox Oven with fan, size 2, GallenKamp, England) at 60 ^oC for 72 hrs, milled to powder by a micro mill (MHM 5, Glen Mills, U.S.A.) and sieved (600 µm). The flour samples were put in zip-lock bags and kept in covered plastic containers until used for analyses.

Determination of Pasting Properties

The pasting profiles of the samples were studied using a Rapid Visco-Analyser (RVA) with the aid of a thermocline for Windows version 1.1 software (Newport Scientific, 1995). The RVA was connected to a personal computer where the pasting properties and curves were recorded directly. Each sample of the starch suspension was prepared by addition of the equivalent weight of 3.0 g dry starch to distilled water to make a total weight of 28.0 g suspension in the RVA sample canister. A paddle was placed inside the canister, which was then placed centrally onto the paddle coupling and inserted into the RVA machine. The measurement cycle (12 min) was initiated by pressing the canister inside the instrument.

Tele:

E-mail addresses: baishng@yahoo.com

The time-temperature regime (temperature curve) of the equipment was as follows: started at a temperature of 50 ^{0}C for 1 min, heated from 50 ^{0}C to 95 ^{0}C in 3 min, then held at 95 ^{0}C for 3 min, and subsequently cooled to 50 ^{0}C over a 4 min period. This was followed by a period of 1 min where the temperature was kept at constant temperature of 50 ^{0}C.

The equivalent sample weight (S) and volume of water (W) were calculated using the formulae below:

Sample weight (S) = $\frac{A \times 100}{100-M}$ and

Volume of water (W) = 28 – S

A = 3 g and M = Moisture content of the sample.

The parameters measured were pasting temperature (temperature at which irreversible swelling of the starch granules occurs, peak viscosity (highest viscosity during the 95 ^{o}C heating stage), holding strength/hot paste stability (lowest viscosity at the end of the 95 ^{o}C heating stage), breakdown value (change in viscosity from peak to holding strength), cold (final) paste viscosity (highest viscosity at end of the 50 ^{o}C cooling stage), and peak time (time it takes to reach peak viscosity).

Sensory analysis of dough

The flour sample was made into dough by using the method of Ekwu *et al*. (2005). Potable water (150 ml) was heated to boiling point before the addition of 50 g flour sample which was mixed with wooden spatula. The mixture was heated with constant stirring until gels formed. The preparation of each sample took an average of 3 minutes. The dough (about 20 g) was wrapped with cling film and put in labeled container. This was kept inside a warmer until they were ready to be served for sensory analysis.

The coded samples were given at room temperature to 10 panelists who were used to eating pounded yam. Samples at each session were presented in duplicates. Panelists were provided with water to rinse their hands during evaluation. They were asked to evaluate for the appearance (colour), texture (smoothness, consistency and elasticity) of the sample using descriptive method. About 10 samples were assessed at a single session in order to prevent fatigue.

Statistical analysis

Randomized Complete Block Design (RCBD) was used for the experimental design while all analyses were carried out in three replicates. The data obtained were evaluated for significant differences in their means using Analysis of Variance (ANOVA) (p<0.05) as the test statistic. Differences between the means were separated using Fisher's Least Significant test as packaged by SAS software.

Results and Discussion

Pasting properties

The effect of pasting properties of raw and pre-gelatinized yam flour samples from all the species are presented in Tables 1-8. Highest values for peak viscosity, with range of 120.17 RVU in *D. dumetorum* to 328.34 RVU in *D. alata*, were obtained in raw flour samples as shown in Table 1. The values decreased significantly (p<0.05) after pre-gelatinization. There was significant difference in peak viscosity values of pre-gelatinized samples of *D. rotundata* and *D. cayenensis* with increase in steaming time. However, there was no significant difference in the pre-gelatinized flour samples of *D. dumetorum* and *D. alata* that were steamed for 20 and 30 min and 10, 20 and 30 min, respectively. Despite the fact that highest peak viscosity value was obtained in raw flour of *D. alata*, least value of 38.30 RVU was obtained in the pre-gelatinized sample that was steamed for 30 min, compared to others. This could be as a result of its low amylose content (Akinwande *et al*., 2013). The low peak viscosity in *D. dumetorum* samples shows that the species has low water binding capacity and is more appropriate for use as weaning foods with its advantage of low bulk density compared to other species (Akinwande *et al*., 2008). Samples that were steamed in autoclave for 5 min had values close to those steamed for 20 min using Barlet steamer. However, lower peak viscosity value of 143.33 RVU was obtained in autoclaved sample of *D. rotundata* compared to value of 148.17 RVU obtained in the sample that was steamed for 30 min in Barlet steamer.

The holding strength values of the yam flour samples varied with species and steaming time (Table 2). The raw flour sample of *D. alata* had the highest holding strength (250 RVU) followed by the pre-gelatinized flour sample of *D. rotundata* steamed for 10 min in the Barlet steamer. There was a general decrease in values obtained in all the species with increase in steaming time. Among pre-gelatinized samples, samples from *D. rotundata* had the highest holding strength values followed by those from *D. dumetorum*. There was no significant difference in values obtained for all the pre-gelatinized *D. alata* samples. Also, there was no significant difference in the values obtained in *D. rotundata* and *D. dumetorum* samples that were steamed for 20 and 30 min in Barlet steamer. The ability of the flour samples to withstand the heating and shear stress had been reported to be an important factor for many processes (Newport Scientific, 1998).

As indicated in Table 3, the raw flour samples from *D. rotundata* and *D. cayenensis* had the highest breakdown values of 149.50 RVU and 149.75 RVU, respectively. Pre-gelatinized yam flour samples steamed in the autoclave and Barlet steamer had low values when compared to their corresponding raw flour samples. Pre-gelatinized flour sample of *D. alata* steamed for 30 min had least value of 2.54 RVU, among others. Breakdown is a measure of susceptibility of cooked starch granules to disintegration and has been reported by Beta *et al*. (2000) to affect the stability of the flour products. A low breakdown value was indicated to suggest that they are more stable under hot condition. Thus, pre-gelatinized flour samples could be stated to have higher stability than the raw flour samples from the same species of yam and can be used as ingredients in food products that have to be subjected high heat and shear force during processing.

Values for final viscosity were observed to be higher than peak viscosity for all the samples (Table 4). Highest final viscosity value was observed in the raw flour of *D. rotundata* (396.88 RVU) while the least value was observed in pre-gelatinized flour sample of *D. alata* steamed for 30 min in Barlet steamer (52.96 RVU). The values obtained using Barlet steamer decreased with increased steaming time. High cold paste viscosity was reported by Nakorn *et al*. (2009) for native and pre-gelatinized rice starch. The final viscosity relates to high resistance to shear and indicates the ability of the flour to form a firm, visco-elastic paste or gel after cooking and cooling owing to re-association of starch molecules (Newport Scientific, 1998).

The setback value was highest in raw flour sample of *D. rotundata* (239.67 RVU), while the least value was recorded in pre-gelatinized *D. alata* sample (17.21 RVU) that was steamed for 30 min in Barlet steamer (Table 5). Values obtained decreased with increased steaming time in Barlet steamer. Pre-gelatinized flour sample of *D. alata* steamed for 30 min had the least setback value indicating minimal amylose retrogradation as the paste is cooled.

Table 1: Peak viscosity (RVU) of raw and pre-gelatinized flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	306.71a	286.63a	120.17a	328.34a
10	236.17b	85.13b	98.63b	58.29b
20	158.96c	64.54c	88.09c	47.34b
30	148.17d	45.92d	86.54c	38.30b
Autoclave				
0	306.71a	286.63a	120.17a	328.34a
5	143.33b	48.46b	90.58a	43.80b

Means followed by different letters down the same minor column are significantly different (p<0.05)

Table 2: Holding strength (RVU) of raw and pre-gelatinized flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	157.21b	136.88a	89.42a	250.00a
10	227.75a	67.92b	88.63a	47.79b
20	156.33b	55.71c	80.71ab	40.46b
30	140.34b	37.13d	76.29b	35.75b
Autoclave				
0	157.21a	136.88a	89.42a	250.00a
5	136.36a	40.29b	83.67a	36.75b

Means followed by different letters down the same minor column are significantly different (p<0.05)

Table 3: Breakdown (RVU) of raw and pre-gelatinized flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	149.50a	149.75a	30.75a	78.13a
10	8.42b	17.26b	10.00b	10.50b
20	7.84b	7.34b	7.37c	6.84b
30	2.63b	8.79b	10.25b	2.54c
Autoclave				
0	149.50a	149.75a	30.75a	78.13a
5	6.96b	8.17b	6.92b	7.04b

Means followed by different letters down the same minor column are significantly different (p<0.05)

Table 4: Final viscosity (RVU) of raw and pre-gelatinized flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	396.88a	364.25a	149.13a	353.55a
10	359.25b	133.04b	117.96b	90.32b
20	234.80c	93.63c	110.46bc	70.92bc
30	193.25d	82.38c	101.80c	52.96c
Autoclave				
0	396.88a	364.25a	149.13a	353.55a
5	184.67b	78.42b	116.21b	69.04b

Means followed by different letters down the same minor column are significantly different (p<0.05)

The pre-gelatinized yam flour samples have lower tendency to retrograde than the raw flour since setback value is an index of retrogradation tendency of starch (Zaidul *et al*. (2003). Retrogradation of starch paste is of considerable practical significance since it affects textural changes that occur in starchy foods.

The pasting time of all the samples ranged between 4.67 and 7.00 min as shown in Table 6. Values obtained in the raw flour samples were lower than those of pre-gelatinized yam flour samples. Least value (4.67 min) was recorded in raw flour of *D. cayenensis* while higher values were obtained from pre-gelatinized flour samples of all the species. The pasting time provides an indication of the minimum time required to cook a given sample.

Table 5: Setback (RVU) of raw and pre-gelatinized flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	239.67a	224.88a	59.75a	103.34a
10	131.50b	65.13b	29.34b	42.92b
20	78.42c	37.92c	29.75b	30.46bc
30	52.92d	45.25c	25.50c	17.21c
Autoclave				
0	239.67a	224.88a	59.75a	103.34a
5	48.33b	38.13b	32.54	32.30b

Means followed by different letters down the same minor column are significantly different (p<0.05)

Table 6: Pasting time (min) of raw and pre-gelatinized flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	4.84c	4.67b	4.94b	4.77c
10	6.94a	7.00a	5.37a	7.00a
20	6.20b	7.00a	5.57a	7.00a
30	6.30b	7.00a	5.40a	6.87b
Autoclave				
0	4.84b	4.67b	4.94b	4.77b
5	6.87a	7.00a	7.00a	6.94a

Means followed by different letters down the same minor column are significantly different (p<0.05)

The pasting temperature was higher in the raw flour of *D. alata* (84.53^{o}C) while the least value was obtained from the raw flour of *D. cayenensis* (79.15 ^{o}C) Table 7. Highest value of pasting temperature (84.53^{o}C) was obtained in the raw flour of *D. alata* while least value of 79.15 ^{o}C was obtained from the raw flour of *D. cayenensis*. While there was significant (p<0.05) difference between values for raw and pre-gelatinized samples from *D. cayenensis* and *D. dumetorum*, there was none for samples from *D. rotundata* and *D. alata*. The pasting temperature is the temperature at the onset of the rise in viscosity. It provides an indication of the minimum temperature required to cook a given sample, which can have implications on stability of other components in the flour, and also indicate energy costs (Newport Scientific, 1998).

In general, pasting properties of pre-gelatinized samples were lower than values obtained in raw flour samples except for pasting time and pasting temperature as indicated in Table 8. All the pasting properties values decreased with increase in steaming time in Barlet steamer, except for breakdown. Also, apart from the pasting time and pasting temperature, samples that were pre-gelatinized for 5 minutes had values that were within the range obtained in pre-gelatinized samples for 20 to 30 minutes in Barlet steamer. Pre-gelatinization in autoclave could thus be advised to be a faster means of pre-gelatinizing yam samples.

Table 7: Pasting temperature (ºC) of raw and pre-gelatinized flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	80.93a	79.15b	80.73a	84.53a
10	81.80a	82.63a	80.94a	82.40a
20	80.93a	82.35a	81.75a	82.39a
30	80.03a	82.03a	82.45a	82.08a
Autoclave				
0	80.93a	79.15b	80.73b	84.53a
5	82.33a	80.19a	82.75a	82.90a

Means followed by different letters down the same minor column are significantly different (p<0.05)

Table 8: Mean effect of species on pasting properties of raw and pre-gelatinized flour samples

ST	PV	HS	BD	FV	SB	PT	PTe
BS							
0	260.46a	158.43a	102.03a	315.95a	156.90a	4.80b	81.33a
10	119.55b	108.02b	11.54b	175.14b	67.22b	6.58a	81.94a
20	89.23bc	83.30b	6.04b	127.45c	44.14c	6.44a	81.79a
30	79.73c	72.38b	7.35b	107.60c	35.22c	6.39a	81.72a
AC							
0	260.46a	158.43a	102.03a	315.95a	156.90a	4.80b	81.33a
5	81.54b	74.27b	7.27b	112.09b	37.82b	6.95a	82.04a

Means followed by different letters down the same minor column are significantly different (p<0.05)

ST – Steaming time (min); PV – Peak viscosity (RVU); HS – Holding strength (RVU); BD – Breakdown (RVU); FV – Final viscosity (RVU); SB – Setback (RVU); PT – Pasting time (min) (RVU); PTe – Pasting temperature (ºC)

Sensory quality attributes

Results for sensory evaluation of different quality attributes are as presented in Tables 9-12. Raw flour from the four species of yam formed lumps when reconstituted into dough and values obtained were significantly different (p<0.05) from those of the pre-gelatinized yam flour samples (Table 9). All pre-gelatinized samples steamed in both autoclave and Barlet steamer formed smooth dough. Variation in steaming time did not affect the smoothness. This implies that that pre-gelatinized flour from all the species can be useful as ingredient in food formulation with good mixing ability.

Considering the elasticity of the samples (Table 10), reconstituted dough from all the raw flour samples from the four species of yam were not elastic. Reconstituted pre-gelatinized *D. alata* and *D. dumetorum* flour samples were not elastic. In contrary, pre-gelatinized *D. rotundata* sample that were steamed for 10 and 20 min in Barlet steamer and that steamed for 5 min in the autoclave were elastic. Also, reconstituted pre-gelatinized *D. cayenensis* flour samples that were steamed for 10 min in Barlet steamer and 5 min in autoclave were elastic. Since elasticity is a desirable attribute of pounded yam by consumers, it means that both *D. dumetorum* and *D. alata* would not be suitable for production of poundoyam.

Only *D. rotundata* pre-gelatinized (steamed for maximum of 10 min) flour sample made dough that was white in colour as shown in Table 11. The colour, however, changed from being white to dirty white (became darker) with increase in steaming time in Barlet steamer. The browning reaction could be due to leakage of amylose fraction that influences solubility. Solubility of yam has been reported to increase with increase in steaming time (Okorie *et al*., 2011). Except for raw *D. dumetorum* flour, both raw and pre-gelatinized flour obtained from all other species produced dough with range of colour from creamy/yellow to dirty brown colour. This discoloration of dough can affect the organoleptic appeal and reduce its acceptability.

Reconstituted dough from all the raw flour samples from the four species of yam were impossible to mold (Table 12). All the dough samples made from *D. rotundata* were easy to mold irrespective of the steaming time. On the other hand, there was no significant difference in the values scored for consistency of all samples from *D. alata* since all were discovered to be impossible to mold. While pre-gelatinized *D. cayennensis* flour that were steamed in Barlet steamer for maximum of 20 min made dough that were easy to mold, all pre-gelatinized *D. dumetorum* samples were difficult to mold. This also confirms that both *D. cayennensis* and *D. dumetorum* are not ideal for production of poundo yam.

Table 9: Smoothness of reconstituted dough from flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	2.50a	2.50a	2.00a	2.00a
10	1.00b	1.00b	1.00b	1.00 b
20	1.00b	1.00b	1.00b	1.00b
30	1.00b	1.00b	1.00b	1.00b
Autoclave				
0	2.50a	2.50a	2.00a	2.00a
5	1.00b	1.00b	1.00b	1.00b

Means followed by different letters down the same minor column are significantly different (p<0.05)

Scoring: 1 = smooth; 2 = small lumps; 3 = big lumps

Table 10: Elasticity of reconstituted dough from flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	2.00a	2.00a	2.00a	2.00a
10	1.00c	1.00b	2.00a	2.00a
20	1.00c	2.00a	2.00a	2.00a
30	1.50b	2.00a	2.00a	2.00a
Autoclave				
0	2.00a	2.00a	2.00a	2.00a
5	1.00b	1.00b	2.00a	2.00a

Means followed by different letters down the same minor column are significantly different (p<0.05)

Scoring: 1 = elastic; 2 = non elastic

Table 11: Colour of reconstituted dough from flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	1.00c	4.00a	1.00c	5.00c
10	1.00c	3.50b	3.00b	5.00c
20	1.50b	4.00a	3.00b	5.50b
30	2.00a	4.00a	4.00a	6.00a
Autoclave				
0	1.00a	4.00a	1.00b	5.00b
5	1.00a	4.00a	3.00a	5.50a

Means followed by different letters down the same minor column are significantly different (p<0.05)

Scoring: 1 = white; 2 = dirty white; 3 = creamy/yellow; 4 = dirty yellow; 5 = light brown; 6 = dark brown

Table 12: Consistency of reconstituted dough from flour samples

Steaming time (min)	*Dioscorea rotundata*	*Dioscorea cayenensis*	*Dioscorea dumetorum*	*Dioscorea alata*
Barlet steamer				
0	3.00a	3.00a	3.00a	3.00a
10	1.00b	1.00c	2.00b	3.00a
20	1.00b	1.00c	2.00b	3.00a
30	1.00b	1.50b	2.00b	3.00a
Autoclave				
0	3.00a	3.00a	3.00a	3.00a
5	1.00b	1.00b	2.00b	3.00a

Means followed by different letters down the same minor column are significantly different ($p<0.05$)

Scoring: 1 = easy to mold; 2 = difficult to mold; 3 = impossible to mold

Conclusion

Values obtained for most pasting properties in the samples that were steamed for 5 min in autoclave were close to those obtained samples steamed for 20 min in Barlet steamer. Therefore, use of autoclave for steaming at higher pressure could be an opportunity to reduce cost of energy in processing of pre-gelatinized yam flour. However, if steaming at atmospheric pressure is to be employed, steaming time could be limited to 20 min. Low breakdown values of the pre-gelatinized samples suggests that they can be used as ingredients in food products that have to be subjected to high heat and shear force during processing. Sensory attributes of pre-gelatinized samples of *D. rotundata* and *D. cayenensis* that were steamed in autoclaved for 5 min and in Barlet steamer for up to 20 min were desirable for instant pounded yam flour. However, pasting properties of pre-gelatinized underutilized *D. dumetorum* flour shows that it could be useful in ingredient formulation as a thickener and gelling agent in pudding and in heat sensitive products like cold deserts, instant soups and salad dressing. It can also find application in instant foods like weaning foods. It is important to encourage its cultivation for industrial application.

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