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Effect of Pre-Cooking and Particle Size Distribution on the Pasting and Functional Properties of Trifoliate (*Dioscorea dumetorum*) Yam Flour

O. A. Abiodun[1,2*], O. A. Omolola[1], O. O. Olosunde[1,2] and R. Akinoso[2]

[1]Osun State Polytechnic, P.M.B. 301 Iree, Osun State, Nigeria.
[2]University of Ibadan, Ibadan, Oyo State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author OAA managed the literature searches, performed the statistical analysis, wrote the protocol, author OAO wrote the first draft of the manuscript, author OOO managed the analyses of the study and author RA designed the study. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aims: The effects of pre-cooking and particle size distribution on the pasting and functional properties of trifoliate yam flours were evaluated.
Study Design: 2 x 2 x 5 factorial experimental design was used for this study.
Place and Duration of Study: The study was carried out in the Department of Food Science and Technology, Osun State Polytechnic, Iree, Osun State, Nigeria, between April 2011 and March 2012.
Methodology: Freshly harvested trifoliate yam (white and yellow cultivars) were peeled, washed, diced, dried, milled and packaged while the precooked flour was cooked for 10 min, dried, milled and packaged. The flour was separated into different particle sizes using sieves 150, 212, 315, 425 and 500 µm. Pasting and functional properties such as bulk density, water absorption capacity, swelling power of the flour samples were evaluated.
Results: Larger percentage of raw flour samples were recovered on sieve size 315 µm and 500 µm respectively while pre-cooked flour samples were retained on the sieve <150 µm and 315 µm respectively. The peak viscosities of the pre-cooked flours were lower than the raw flours and these decreased with increase in particle size. Bulk density and

**Corresponding author: E-mail: funmiabiodun2003@yahoo.com;*

water absorption capacity ranged from 0.67 to 1.00 g/cm^3 and 1.50-4.90 mL H2O/g respectively. Pre-cooked yellow trifoliate yam flour had higher bulk density value than the raw yellow flour at 212 µm but no significant difference (p = 0.05) exists between them. The highest water absorption capacity (4.9 mL H2O/g) was observed in the pre-cooked yellow trifoliate yam flour at 315 µm size sieve. Pre-cooked flour of white trifoliate yam had higher swelling power (9.86) at 150 µm particle size and 80ºC. The swelling power of the raw and pre-cooked flours increased with increase in temperature.
Conclusion: The pre-cooked trifoliate yam flours with 150-315 µm particle sizes produced flours with higher pasting and functional properties.

Keywords: Cultivar; functional properties; particle size; pasting properties; pre-cooking; trifoliate yam.

1. INTRODUCTION

Trifoliate yam (*D. dumetorum*) is a lesser known yam among the yam species and is underutilized. The tubers are known as three leaved yam, bitter yam and cluster yam and the plant is easily identifiable by its trifoliate compound leaf which twines in anti-clockwise direction. The tubers are eaten during the time of famine or scarcity and are usually boiled with peel and eaten as boiled yam. Post harvest hardening limit their production and commercialization outside production zones thereby hampering their economic and nutritious value as food [1]. The global production of yam has risen significantly over the years leading to large amount of losses usually during storage in developing countries like Nigeria. Yam flour production enhances the utilization and storability of yam [2]. Processing of yam into industrial products such as flour would not only prevent postharvest loss but also promote its use industrially and increase the income of the yam producers thereby encourage more production [3]. Heat-moisture treatment is known to affect the chemical and physical characteristics of roots and tubers by changing the internal structure, starch-sugar transformation, gelatinization of starch and solubilization of cell-wall [4]. Cooking was also reported to consolidate the pulp into meal, displacing the air spaces in the material [5] and improves the nutritional and aesthetic value of the product [3,6-7]. Particle size of flour is among the factors that affect the quality of the end product of a food [8-10]. Although the particle size of other yam species had been studied by Iwuoha [7], that of trifoliate yam flour had not been investigated, leading to dearth of information on the pasting and functional characteristics of trifoliate yam flour. The objective of this work is to study the effect of particle size and pre-cooking on the pasting and functional properties of trifoliate yam flour.

2. MATERIALS AND METHODS

2.1 Materials

The trifoliate yam tubers (White and Yellow) were collected from a farm at Osogbo, Osun State, Nigeria.

2.2 Methods

2.2.1 Preparation of raw flour

The freshly harvested yam tubers were washed, drained and peeled. The peeled tubers were sliced and dried in the hot air oven at 60ºC for 48 hrs. The dried chips were milled into flour with hammer mill and sieved with American standard sieve (No 10). The flour samples were sealed in polythene bag.

2.2.2 Preparation of pre-cooked flour

Modified method of Ekwu et al. [11] was used for the preparation of pre-cooked sample. The freshly harvested yam tubers were washed, peeled, diced and washed with portable water. They were pre-cooked for 10 min in water bath maintained at 100±2ºC. The samples were dried in an oven set at 60ºC for 48 hrs. The dried chips were milled into flour with hammer mill and sieved with American standard sieve (No 10). Table 1 showed the sample code and the designation.

Table 1. Sample code and designation

Sample	Designation
WR	Raw white trifoliate yam flour
YR	Raw yellow trifoliate yam flour
WS	Cooked white trifoliate yam flour
YS	Cooked yellow trifoliate yam flour

2.2.3 Analyses

2.2.3.1 Pasting properties of flour

The pasting profile of the flour sample was studied using a Rapid Visco-Analyzer (RVA) (Newport Scientific Pty.Ltd) with the aid of a thermocline for windows version 1.1 software [12]. The RVA was connected to a personal computer where the pasting properties and curve were recorded directly. Flour suspension was prepared by addition of the equivalent weight of 3.0 g flour to distilled water to make a total of 28.0 g suspension in the RVA sample canister. The flour suspension temperature was held at 50ºC for 1 min and later heated to 95ºC for 3 min. It was held at 95ºC for 3 mins before the sample was subsequently cool to 50ºC over a 4 mins period. This was followed by a period of 1 min where the temperature was kept at constant temperature of 50ºC. The equivalent sample weight (S) and volume of water (W) was calculated using formular below:

Sample weight (S) = (A X 100)/(100-M)
Volume of water (W) = 28-S
Where A = 3 g
S = Calculated sample weight for RVA
M = Moisture content of the sample
W = Volume of water

Parameters measured (RVA units) were:

Peak viscosity:	Highest viscosity during 95ºC heating stage
Holding strength:	Lowest viscosity at the end of 95ºC heating stage.
Breakdown:	Change in viscosity from peak to holding strength.
Cold paste (final) viscosity:	Highest viscosity at the end of 50ºC cooling stage.
Setback:	Change in viscosity from holding strength to final viscosity.

2.2.3.2 Particle size distribution

The particle size distribution of trifoliate yam flour (50 g) from each production method was carried out using a sieve analysis technique with the aid of Endecotts Test Sieve Shaker (model 1 MK11-11381, London, UK). Sieves of different apertures (500, 425, 315, 212 and 150 µm) and pan were used by placing them in the shaker for 10 min. The flour retained on each sieve was weighed and the mean particle size (MPS) of the flour determined. The amount from each sieve was recorded as a percentage of total recovery [9].

2.2.3.3 Bulk density

The method used by Udensi and Okaka [13] was adopted. Bulk density was determined by weighing 3 g of each sample into 10 ml graduated cylinders and tapping ten times against the palm of hand. The volume of the flour after tapping was recorded and bulk density was expressed as g/ml.

2.2.3.4 Water absorption capacity determination

Flour sample (1 g) from each treatment was weighed into dry centrifuge tube. Distilled water was mixed with the flour to make up to 10 ml dispersion. It was then centrifuged at 3500 rpm for 15 min. The supernatant was discarded while the tube with its content was reweighed. The gain in mass is the water absorption capacity of the flour sample [7].

2.2.3.5 Swelling power determination

Swelling power of yam flour was determined according to Peloni et al. [14]. Flour sample of 0.2 g (dry starch basis) was mixed with 18 g of distilled water into glass tubes with coated screw caps. The tubes were placed in a shaking water bath at 60, 70, 80 or 90ºC for 30 min. After that, the tubes were taken from the bath, dried and weighed. The weight of the mixture was completed to exactly 20 g. The tubes were closed, inverted for homogenization and centrifuged at 1700 g for 5min. The supernatant was removed carefully and swelling power was determined as sediment weight divided by dry weight of flour (g/g).

2.2.4 Statistical analysis

2 x 2 x 5 factorial experimental design was used for this study with 2 cultivars, 2 processing methods and 5 particle size distributions. All analyses were carried out in three triplicates. The mean and standard deviation of the data obtained were calculated. The data were evaluated for significant differences in their means with Analysis of Variance (ANOVA) ($p = .05$). Differences between the means were separated using turkey test as packaged by SPSS (17.0) software.

3. RESULTS AND DISCUSSION

The mean particle size of trifoliate yam flour obtained for the two cultivars are presented in Table 2. Larger percentage of raw flour samples were recovered on sieve size 315 µm and 500 µm respectively while majority of the pre-cooked flour particles were retained on >150 µm and 315 µm respectively. Smaller particle sizes were obtained when the cultivars of trifoliate yam tubers were pre-cooked signifying varying particle size flours which could be used as thickeners, puddings and food formulation.

Mean particle size of flour has been observed to influence the physicochemical properties such as swelling power, paste clarity and water-binding capacity of the flour and textural characteristics of food products derived from such flour [10,15-16]. Nwanekezi et al. [10] observed that the suitability of flour in infant based products depends on the smoothness of the reconstituted end product which is greatly influenced by the particle size. Fine granules of taro starch were reported to improve the binding and reducing breakage of a snack product [16-17]. Also, Iwuoha [6] observed that the range of particle size in yam depends on the species and the degree of processing. Therefore, particle size characterization enables the food processors have wide range of flour for different purposes.

The pasting properties are shown in Table 3. Peak viscosity of raw and cooked trifoliate yam flour ranged from 112.38 to 284.82 RVU, holding strength was from 9.34 RVU (500 µm in precooked white flour) to 48.25 RVU (500 µm in raw white flour). Breakdown viscosity were from 2.50 RVU (425 µm in pre-cooked yellow flour) to 257.36 RVU (150 µm in raw white flour) while the final viscosity of the flour ranged from 28.75 RVU (212 µm in pre-cooked yellow flour) to 131.71 RVU (150 µm in raw white flour) with setback viscosity ranging from 19.05 to 104.26 RVU.

Higher peak viscosities were observed in the raw trifoliate yam at 150 µm. The pre-cooked flours had lower peak viscosities than the raw flours indicating low starch contents in the pre-cooked flour. Reduction in the starch contents of the pre-cooked flours may be due to leaching of the amylose in cooking water. High temperature weakens the starch granules of flour leading to improved solubility in the cooking medium [19]. The peak viscosity of the raw and pre-cooked yam flour samples decreased as the particle size increased. This implies that the smaller the surface area of the flour, the higher the viscosity of the product. Peak viscosity occurs at the equilibrium point between swelling and polymer leaching (which cause an increase in viscosity) and rupture, and polymer alignment (which cause it to decrease). Increase in viscosity of gelatinized food was explained to depend more on the starch content of the product [20].

Higher holding strength was observed in raw white trifoliate yam at 500 µm and raw yellow trifoliate yam flour at 425 µm indicating low cooking loss and superior eating quality [21]. During the holding period, the flour sample was subjected to a period of constant high temperature and mechanical shear stress, which further disrupted the starch granules. The ability of the flour samples to withstand the heating and shear stress had been reported to be an important factor for many processes [12].

The pre-cooked flour exhibited lower breakdown in viscosity but the least was in pre-cooked yellow flour at 425 and 500 µm. Low breakdown values suggest high stability of the flour under hot conditions. Thus, the yellow pre-cooked flour samples have higher stability at 425 and 500 µm than the other flour samples. Breakdown is a measure of susceptibility of cooked starch granules to disintegration and has been reported by Beta et al. [22] to affect the stability of the flour products.

The final viscosities of the WR and YR decreased after cooking and cooling while that of WS and YS decreased at 150, 212 and 315 μm. At 425 and 500 μm, the final viscosities of the pre-cooked flours increased than the peak viscosity indicating their high resistance to shear stress during cooking and cooling. Final viscosity 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 [12].

The least setback value was observed in YS at 212 μm indicating minimal amylose retrogradation as the paste is cooled [21]. The pre-cooked yam flour samples have lower tendency to retrograde than the raw flour. Setback value is an index of the tendency of the cooked flour to harden on cooling due to amylose retrogradation [23]. Retrogradation of starch paste is of considerable practical significance since it affects textural changes occurring in starchy foods.

WS at 150 μm required more time for cooking than the other flours. The pasting time provides an indication of the minimum time required to cook a given sample. No significant difference (p=.05) existed in the pasting temperatures of the flour samples.

The bulk densities of trifoliate yam flours are presented in Table 4. Bulk density of the WS was higher at 150 μm and was significantly different (p=.05) from other flours. At 212 μm, the raw white trifoliate yam (WR) had higher value (0.98 g/cm^3) than the pre-cooked and raw yellow flours. The least value at 315 μm was in the raw white trifoliate yam flour. The pre-cooked yellow trifoliate yam flour was significantly different (p = .05) from other yam flour at 315 μm. YR was significantly different (p =.05) from other flours at 425 μm while at 500 μm, the raw flours had higher bulk densities than the pre-cooked flour samples.

Particle size and pre-cooking method had slight effect on the bulk densities of raw and pre-cooked trifoliate yam flour. Mayaki et al. [5] observed higher bulk density for pre-cooked breadfruit flour than the raw flour. The bulk densities reported by Igyor et al. [24] and Mayaki et al. [5] for *D. cayenensis*, *D. bulbifera*, *D. rotundata* and breadfruit flours were lower than the observed values for trifoliate yam flour. Okorie et al. [25] observed no effect on bulk density of yam flour after blanching but reported significant effect of particle size and variety of yam on bulk density. Bulk density is reported to be a function of particle size; particle size is inversely proportional to bulk density [26]. Increase in bulk density increased the sinkability of powdered particles which aids wetting by aiding their ability to disperse [13].

Table 2. Percentage means particle size distribution of trifoliate yam flour

Sample	<150 µm	150 µm	212 µm	315 µm	425 µm	500 µm	>500 µm
WR	3.00±0.02c	7.38±0.01a	8.36±0.01b	42.54±0.02a	2.38±0.01c	22.98±0.01ab	13.36±0.01b
YR	3.72±0.01c	2.50±0.02d	5.80±0.01d	35.00±0.01b	7.58±0.01a	30.14±0.02a	15.26±0.01a
WS	38.22±0.01a	6.48±0.01b	6.48±0.01c	33.62±0.01d	2.62±0.01b	10.42±0.01b	2.16±0.01d
YS	29.94±0.01b	5.44±0.02c	8.50±0.01a	34.74±0.01c	2.12±0.01d	12.44±0.01b	6.82±0.01c

[a]*Values with the same letter down the column are not significantly different (p = .05) from each other.*

Table 3. Effect of pre-cooking and particle size on the pasting properties of trifoliate yam flour

Sample	Particle size (µm)	Peak viscosity (RVU)	Holding strength (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Pasting Time (min)	Pasting temp oC
WR	150	284.82±1.51a	27.46±0.66g	257.36±1.85a	131.71±0.41a	104.26±1.07a	4.55±0.02f	48.12±0.37a
	212	231.18±0.45b	45.50±1.17b	185.68±0.72c	116.19±0.03c	70.69±1.21c	6.07±0.09abc	48.44±0.03a
	315	231.41±0.72b	45.50±1.17b	189.10±0.45c	108.88±0.18f	66.57±0.45cd	6.58±0.04ab	48.21±0.07a
	425	188.36±0.09e	38.34±0.47d	150.03±0.39d	106.32±0.14g	67.99±0.33cd	6.18±0.25abc	47.98±0.03a
	500	117.42±0.23g	48.25±0.35a	69.17±0.13fg	110.65±0.14e	62.40±0.21e	6.02±0.02abcd	48.11±0.07a
YR	150	283.75±0.35a	38.59±0.59d	245.27±0.37b	104.06±0.86h	65.48±1.44de	5.29±0.11e	48.08±0.11a
	212	207.97±0.16c	35.25±0.35e	180.22±1.41c	113.62±0.52d	78.88±0.18b	6.15±0.21abc	48.13±0.18a
	315	199.70±0.66d	42.95±0.08c	156.76±0.59d	112.05±0.08e	69.14±0.12cd	6.09±0.12abc	47.98±0.03a
	425	167.62±0.53f	47.50±0.71ab	120.13±0.18e	117.79±0.30b	70.29±0.41c	5.91±0.13bcde	47.93±0.10a
	500	112.38±0.18g	41.37±0.54c	71.01±0.72fg	88.09±0.12	46.72±0.42f	5.91±0.15bcde	48.18±0.25a
WS	150	91.68±0.92h	27.64±0.05g	64.05±0.88g	64.32±0.01l	36.69±0.03h	6.64±0.02a	48.23±0.04a
	212	88.46±2.07h	10.36±0.09ij	78.10±1.98f	54.14±0.05o	43.78±0.04fg	5.62±0.03de	48.18±0.02a
	315	50.04±0.06j	12.22±0.31i	37.82±0.37h	35.92±0.71r	23.71±1.03j	5.32±0.03de	48.33±0.05a
	425	37.57±0.72k	31.72±1.46f	5.85±0.74ij	75.22±0.16k	43.50±1.30fg	6.09±0.11abc	48.64±0.04a
	500	24.31±0.27l	9.34±0.23j	14.98±0.04i	51.49±0.13p	42.15±0.10g	5.63±0.01cde	47.93±0.10a
YS	150	91.08±0.13h	28.18±0.11g	62.91±0.02g	55.71±0.06n	30.04±2.49i	5.23±0.62ef	48.36±0.00a
	212	78.67±0.94i	9.71±0.18j	68.96±0.76fg	28.75±0.35s	19.05±0.53k	5.21±0.01ef	48.45±0.01a
	315	56.27±0.09j	41.65±0.15c	14.60±0.09i	77.90±0.03j	36.26±0.12h	5.47±0.01cde	47.88±0.17a
	425	31.63±0.06k	29.13±0.18g	2.50±0.11j	49.50±0.71q	20.38±0.53jk	5.68±0.17cde	48.43±0.61a
	500	23.79±0.30l	18.71±0.06h	5.09±0.36ij	62.26±0.10m	43.56±0.04g	5.92±0.12bcde	48.33±0.47a

[a]*Values with the same letter down the column are not significantly different (p = .05) from each other.*

Table 4. Effect of pre-cooking and particle size on the bulk density (g/cm^3) of trifoliate yam flour

Sample	150 µm	212 µm	315 µm	425 µm	500 µm
WR	0.80 ± 0.01c	0.98 ± 0.02a	0.77 ± 0.02c	0.82 ± 0.02a	0.94 ± 0.03a
YR	0.87 ± 0.02b	0.91 ± 0.02b	0.81 ± 0.02b	0.67 ± 0.01b	0.88 ± 0.01b
WS	0.91 ± 0.02a	0.86 ± 0.02c	0.82 ± 0.03b	0.89 ± 0.01a	0.80 ± 0.02c
YS	0.80 ± 0.02c	0.92 ± 0.01b	0.88 ± 0.01a	1.00 ± 0.11a	0.82 ± 0.02c

[a]*Values with the same letter down the column are not significantly different ($p \leq 0.05$) from each other.*

The least water absorption capacity was observed in the YR with the lowest value in 425 µm (1.5 mL H2O/g) (Table 5). The WR absorbed more water at 150 than the pre-cooked samples but at 212, 315, 425 and 500 µm, the pre-cooked flour had higher values than the raw flours. The highest water absorption capacity (4.9 mL H2O/g) was observed in the pre-cooked yellow trifoliate yam flour at 315 µm size sieve. Aboubakar et al. [27] reported that small particle size (75 µm) flours absorbed more water than larger ones (150 and 250 µm). This finding was contrary to the observed values for trifoliate yam flour. Water absorption capacity increased from 150 -315 µm in the pre-cooked flour and decreased slightly at 425 µm. YS absorbed more water at particle size 315 µm while YR had lower water absorption capacity than the other flours. The ability of starch to absorb water is an indication of its moisture stability more especially in the food industry [28]. Water binding capacity of starches also provides evidence of the degree of intermolecular association between starch polymers due to associative forces such as hydrogen and covalent bonding [29].

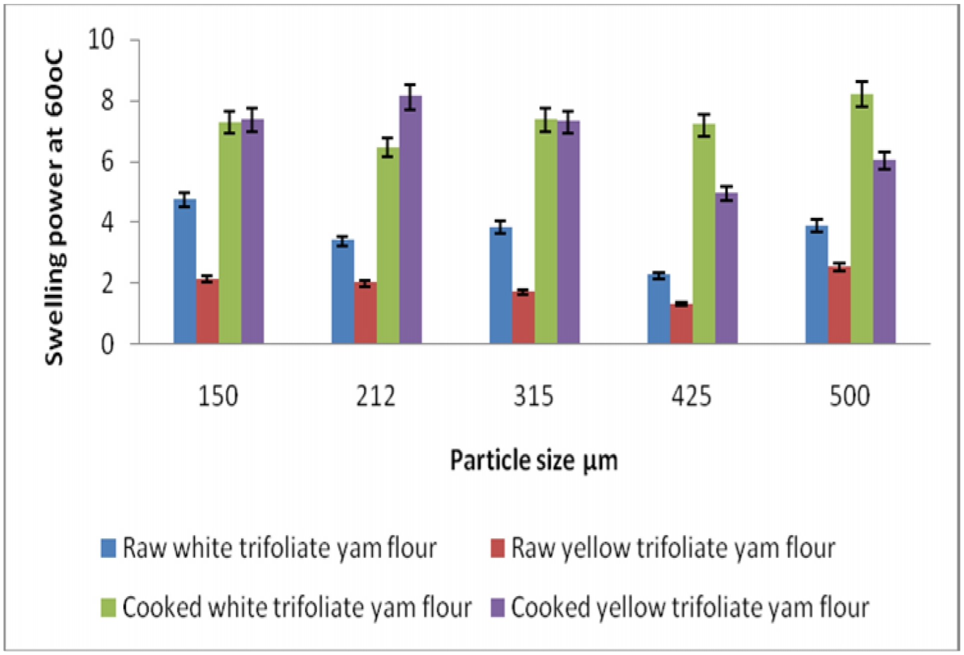
Table 5. Effect of pre-cooking and particle size on the water absorption capacity (mL H_2O/g) of trifoliate yam flour

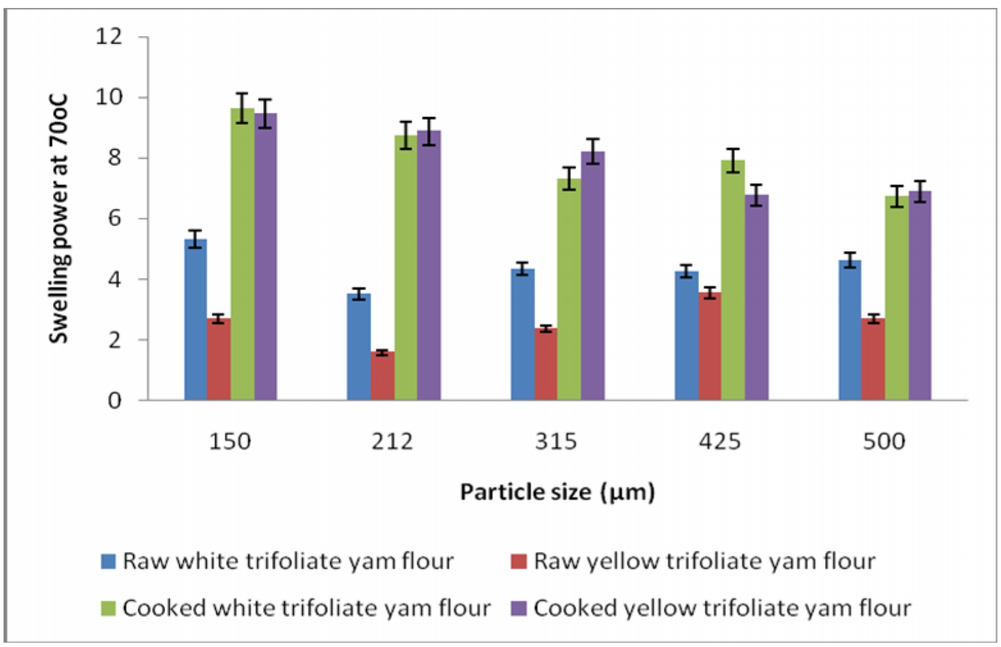
Sample	150 µm	212 µm	315 µm	425 µm	500 µm
WR	4.20 ± 0.07a	2.90 ± 0.04c	3.80 ± 0.06c	3.05 ± 0.04b	3.90 ± 0.02b
YR	2.40 ± 0.06d	2.65 ± 0.02d	2.35 ± 0.02d	1.50 ± 0.09c	2.70 ± 0.01c
WS	3.80 ± 0.01b	3.75 ± 0.01b	4.10 ± 0.06b	3.61 ± 0.04a	3.85 ± 0.04b
YS	3.55 ± 0.02c	3.95 ± 0.01a	4.90 ± 0.01a	3.63 ± 0.01a	4.30 ± 0.02a

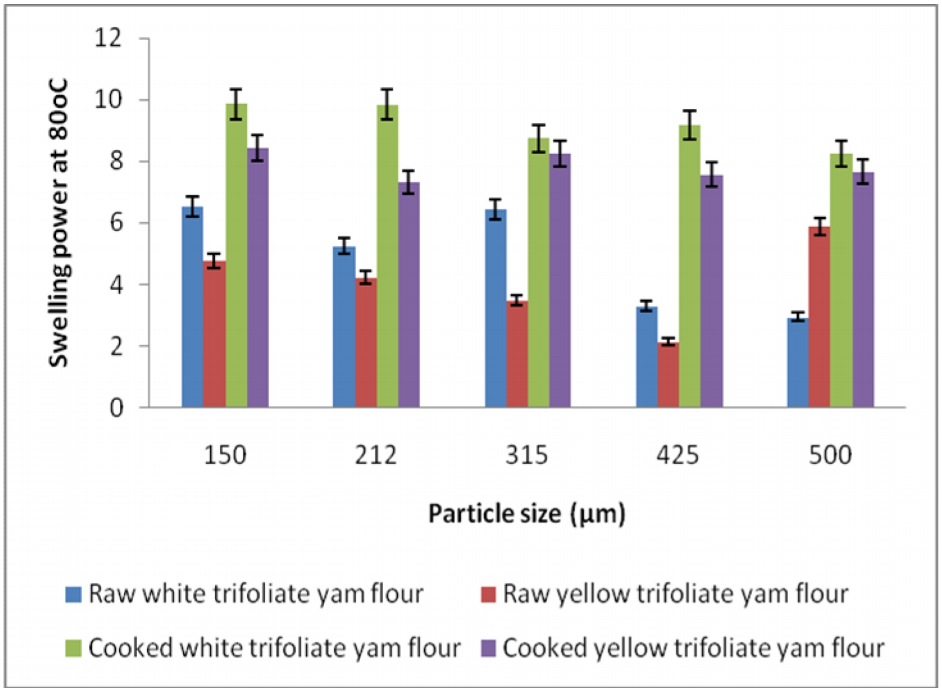
[a]*Values with the same letter down the column are not significantly different ($p \leq 0.05$) from each other*

YS exhibits lower values in swelling power at 60, 70 and 80ºC and at varying particle sizes but increased rapidly at 90ºC (Fig. 1). The swelling power increased with increased in temperature for raw and pre-cooked samples. WS had higher swelling power (9.86) at 150 µm and 80ºC. Pre-cooked flour with particle sizes 150 to 425 µm had higher swelling power than 500 µm particle sizes at 80ºC. There were slight reduction in the swelling power of pre-cooked flours at 90ºC but there was increase in the swelling power of YR (7.79) at 90ºC and 150 µm. The values obtained were within the range observed for *D. alata* varieties [30].

The Pre-cooked flours from the trifoliate cultivars had higher swelling power than the raw flour samples. This was due to leaching of the straight chain amylose into the cooking medium. Amylose was reported to restrict swelling and that starch granules show complete swelling after amylose has been leached out of the granules [21]. Thus, the lower swelling power values obtained for the raw flours at 60 to 80ºC could be as a result of highly ordered internal arrangement in their starch granules [30]. The reduction in the swelling power of pre-cooked flours may be as a result of the treatment given to the flour which reduced its ability to swell at higher temperature more than 80ºC. Swelling power is largely controlled by the strength and character of the micellar network within starch granules. Swelling power is an indication of the water absorption index of the granules during heating and it reflects the extent of the associative forces within the granules [31-33].







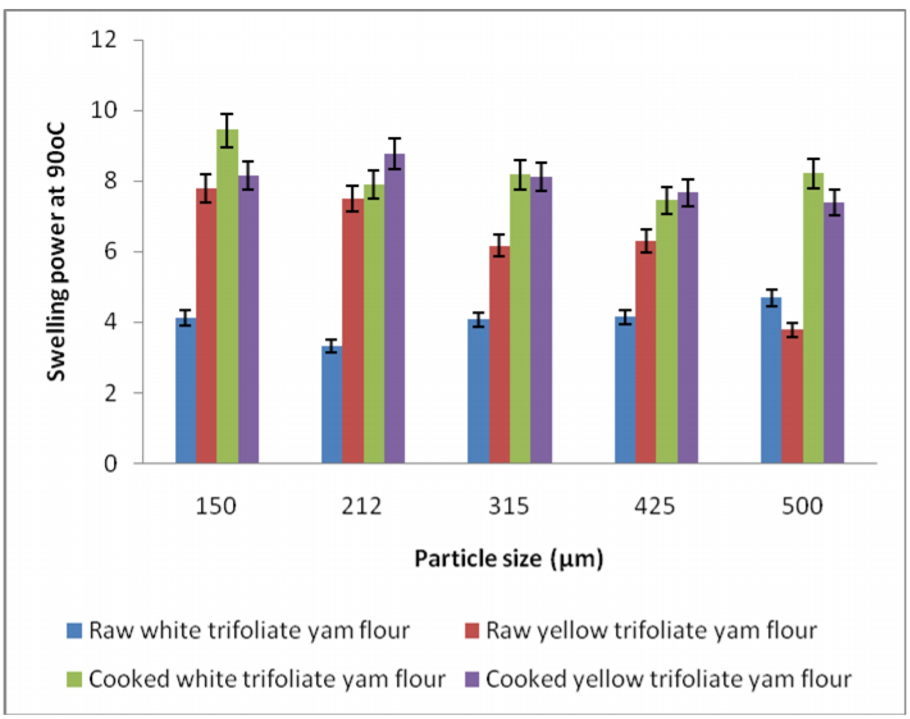


Fig. 1. Effect of pre-cooking and particle size distribution on the swelling power of trifoliate yam flour

4. CONCLUSION

The properties of raw and pre-cooked trifoliate yam flours were comparable to other yam species. Pre-cooking improved the functional properties of the flour and therefore makes the flour important in food formulation. Low viscosities of the pre-cooked flour make it suitable for infant baby food formulation. The effect of particle size depends on the cultivar of yam and the pre-cooking method. Therefore, flours with particle sizes ranging from 150-315 μm would have a wide application in the food industry.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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