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Quality Characteristics of Processed Flours from Trifoliate Yam (*Dioscorea dumetorum*) as Influenced by Steeping and Boiling in Varying Concentration of Trona Solution over Time

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ABSTRACT

The use of additives (trona solutions) in pre treatment of stored trifoliate yam in order to reduce cooking time and evaluation of quality characteristic of the resultant flours were studied. Selected tubers of trifoliate yam were cleaned and cut into chunks of 5 cm each. The cut portions were steeped in different concentrations of trona at loading rate of 1:2 (m/v) for 24 h. After steeping some portions were sliced to 5.0 mm thickness and sun-dried (3 days), milled and sieved with 1.0 mm mesh sieve. The remaining portions were boiled in different media for 120 min, dried, milled into flour. The flour samples were analyzed using standard methods for the proximate and functional properties. Steeping in varying concentration of trona gave significant decrease ($p<0.05$) in protein, gelatinization and boiling temperatures but increased the moisture value of the flour as the trona concentration increased. Boiling in different media after steeping in trona solution gave protein values: 6.62 for SSL; 7.20 for FPS and 7.12 for FWT; these did not differ at $p>0.05$. Trona solution was effective in reducing boiling temperature and modified the proximate and functional properties of trifoliate yam flours.

Key words: Trifoliate yam, trona, protein, water absorption, gelatinization temperature

INTRODUCTION

Trifoliate yam (*Dioscorea dumetorum*) is one of the numerous tropical tubers that are yet to be exploited and is fast being driven to extinction despite, being good source of phyto-proteins, carbohydrate, vitamins and minerals for human nutrition (Mensah and Sefa-Dedeh, 1991; Medova *et al.*, 2005; Alozie *et al.*, 2009). Worst also, the crop is yet to attract adequate research interest in tapping the potentials and its culinary uses are relegated to the back ground (Coursey and Ferber, 1979; Degras, 1993).

Onuegbu *et al.* (2011) reported that so far the yam has found no industrial application. Several factors might be responsible for the apparent neglect suffered by the crop: like several other yam species, the Trifoliate Yam (TLY) contains toxic principles, prominent among them is dioscorine (a convulsive alkaloid with molecular weight, $C_{13}H_{19}O_2N$) which causes a knock down effect especially to humans, mammals, birds and fish (Nkala *et al.*, 1994). Also, the tubers of three-leaved yam are susceptible to a hardening phenomenon which is characterized by loss of ability to soften during cooking (Medova *et al.*, 2005). Some workers have associated the hard-to-cook defect to pectin-phytate interactions and the lignifications of aromatic compounds which accumulate at the cell wall surfaces where they act as precursors in lignification-like reactions.

Overcoming the hard-to-cook defect and removing the plant toxin in trifoliate yam might improve the utilization of the flour in food formulation. Medova *et al.* (2005) reported that storage at a low temperature and relative humidity (15°C, 59 RH) can slow down the hard-to-cook phenomenon.

The tubers of trifoliate yam, when properly processed like some other yams, can be used in the production of yam flakes; instant flour for the bakery sector or starch in diverse pharmaceutical preparations (Faboya and Asagbara, 1990; Ukpabi, 2010).

In Eastern Nigeria, where several cultivars of trifoliate yam are grown, some cultivars are cooked within 24 h just after harvest so as to avoid the hard-to-cook-effect and eaten with oil and spices. When the yam is stored for some period of time, cooking such yam ordinarily might last for 24 h or more. As such, a variety of pre-treatments are applied on the yam so as to reduce the cooking time and destroy the toxic principles. These pre treatments vary from one community to another and may include: steeping the tuber in trona solution (hydrated sodium carbonate, $Na_2CO_3.NaHCO_3.2H_2O$) over night and boiling with the trona solution for varying durations of time; in others the trona solution will be discarded after steeping and the tuber boiled in fresh water or fresh trona solution will be introduced as cooking medium. These indigenous pre treatments have been used over several decades in cooking trifoliate yam and very few studies have been carried out on the implications of using trona solution as cooking medium to reduce process time (Onuegbu *et al.*, 2011). It might be useful to exploit the above pre treatments for production of flour and to evaluate the extent of modification of the resultant flour by trona solution.

The current study investigates the implications of trona solutions as steeping and boiling medium for peeled tubers of trifoliate yam for flour production. The evaluation will include effects of concentration of trona solution, boiling time, boiling in various solutions on the proximate and physicochemical properties of flours of trifoliate yam.

MATERIALS AND METHODS

The tubers of trifoliate yam used in the study were harvested from a farm at Isiala Mbano local Government Imo State Nigeria on the 14th August, 2012. These were immediately conveyed to the Food Processing laboratory at Federal University of Technology Owerri Nigeria and allowed to store for 14 days. Thereafter, the yam tubers were sorted to remove bruised, cut and unwholesome tubers. The selected tubers were pared off, washed, cut into chunks (5 cm thickness) and divided into six equal portions. Each portion was steeped in already prepared concentrations (0.0, 2.5, 5.0, 7.5, 10.0, 12.5 {m/v, db} of trona at loading rate of 1:2 (mass: volume) for 24 h. After 24 h, some portions were steep-out and further sliced to approximately 5.0 mm thick, sun-dried (3 days), milled into flour to pass through 1.0 mm mesh sieve and packed with hermetic sealing; and stored in dry condition.

Another steep-out portion was boiled in various medium {Spent-steep Liquor (SSL), freshly prepared trona solution (FPS) and Fresh tap water (FWT)} for 120 min. Samples were generated from (0.0, 30, 60, 90 and 120 min) as boiling progressed. Thereafter the boiled chunks were cooled, sliced, dried and milled into flour, sieved and packaged as stated above.

Proximate composition: The moisture, crude protein, crude fat, crude fibre, ash and carbohydrate and pH were determined following the methods of AOAC (1990).

Swelling index: The swelling index was determined by the method described by Ukpabi and Ndimele (1990). Three grams portion (dmb) of flour was transferred into a clean dry graduated (50 mL) cylinder. The flour was gently levelled and the volume recorded. Distilled water (30 mL) was added to the sample and the cylinder was swirled and allowed to stand for 60 min while the change in volume (swelling) was recorded every 15 min. The swelling power of the flour was calculated as a multiple of the original volume.

Water absorption capacity: Water absorption capacity was determined by the method of Abbey and Ibeh (1988). One gram of sample was weighed and transferred into a clean centrifuge tube of known weight. Distilled water was mixed with the flour to make up to 10 mL dispersion. This was centrifuged at 3500 rpm for 15 min. The supernatant was decanted and the tube with its content reweighed. The gain in mass is the water absorption capacity of the four.

Oil absorption capacity: The method described by Abbey and Ibeh (1988) was followed in determining the oil absorption capacity. The sample of flour (1.0 g) was weighed and placed in a clean centrifuge tube of known weight. Groundnut oil was mixed with the flour to make up to 10 mL dispersion. The tubes were centrifuged at 3500 rpm for 15 min. The supernatant was discarded and the tube reweighed. The gain in mass is recorded as the oil absorption capacity.

Blue value index: The method described by Kawabata *et al.* (1981) was adopted in the determination of Blue Value Index (BVI). Three grams of sample was weighed into a 30 mL volumetric flask, dispersed with distilled water and then made up to the mark with distilled water. The dispersion was filtered through a Whatman No. 42 filter paper. A 10 mL aliquot of the filtrate was treated with 0.1 N iodine solution to a bluish-black end-point, using phenolphthalein (4 drops) as indicator. The BVI was derived as follows:

$$\text{BVI (ppm)} = (V_D/V_A)\ (V_1/M_a)\ N_a/1000)\times 10^6$$

Where:

V_D = Total volume of dispersion

V_A = Volume of aliquot used

V_1 = Titre value

M_s = Mass (dmb) of flour

N_a = Normality of iodine solution

Solubility: The method described by Udensi and Onuora (1992) was followed. Flour dispersion was prepared by dispersing 1.0 g of flour in distilled water and made up to 10 mL. It was allowed to stand for 60 min while it was stirred every 10 min and subsequently allowed to settle for 15 min. Thereafter, 2 mL of supernatant was transferred to an already weighed petri dish using a pipette. The supernatant was evaporated to dryness and reweighed. The Total Soluble Solid (TSS) was calculated as:

$$\text{TSS (\%)} = (V_s/2M_s)\ (M_e\text{-}M_d)\times 100$$

Where:
V_s = Total supernatant/filtrate
M_d = Mass of empty, dry petri dish
M_e = Mass of petri dish plus residual solids after evaporative drying
M_s = Mass of sample used for dispersion

Gelatinization temperature and boiling point: The method of Onwuka (2005) was adopted in the determination of gelatinization temperature. The flour (10 g dmb) was dispersed in distilled water in 350 mL beaker and made up to 100 mL flour dispersion. A thermometer was clamped on a retort stand with its bulb submerged in the suspension with a magnetic stirrer and the system heated. The heating continued until the suspension began to gel and the corresponding temperature was recorded. The temperature at boiling point was also recorded.

Experimental design: The data from the process which involved steeping (SSC), followed by boiling in solutions of diverse nature (NBS), over time (BLT) fitted into SSC {6}×NBS {3}×BLT {5} experimental design. Data were subjected to 3-way analysis of variance (ANOVA) using Statistical Analysis System (SAS) version (SAS, 2000) and the means separated following the least significant difference.

RESULTS AND DISCUSSION

Effect of steeping in trona solution on proximate values of flour of trifoliate yam: The result of triplicate data, standard deviation and significance of flours generated after steeping in varying concentration of Trona are shown in Table 1. The sample generated from 12.5% steeping solution was found to retain the highest moisture 15.2% while the control (0.0%) was least, 11.88%. The moisture content of the resultant flour was found to increase significantly ($p<0.05$) as the steeping concentration of trona increased. This might suggest that trona solution (hydrated sodium carbonate, $Na_2CO_3.NaHCO_3.2H_2O$) has the ability to crack the cellular structure or soften the plant tissue thereby allowing the macromolecules to absorb water and plasticize. The imbibed trona solution might become bound to the plant tissue in such a way that conventional drying seemed impossible remove the diffused moisture. According to Uzoma and Osuji (2004), the increase of absorbed moisture may be attributed to the high cell damage due to coupled effects of high trona concentration and the long boiling time. High moisture is not advantageous from storage stability stand point (Olorunda, 1979; Rockland and Stewart, 1981).

Table 1: Mean proximate composition of flour from three-leaved yam (tly) tubers as affected by steeping in varying strength trona solution

Steeping solution conc.	Proximate composition (%, dmb)					
(% M/V dmb)	Moisture	Protein	Fat	Fiber	Ash	Carbohydrate
0.0	11.88 ± 1.12^{e}	9.85 ± 0.61^{a}	3.65 ± 0.73^{b}	2.96 ± 0.56^{a}	2.77 ± 0.08^{bc}	70.35 ± 2.25^{a}
2.5	12.63 ± 1.10^{d}	7.97 ± 1.66^{b}	4.19 ± 1.00^{a}	3.13 ± 0.89^{a}	3.35 ± 0.56^{b}	65.43 ± 7.07^{a}
5.0	13.80 ± 0.87^{bc}	7.46 ± 1.44^{b}	4.20 ± 0.79^{ac}	3.08 ± 0.54^{a}	3.14 ± 0.72^{bc}	71.99 ± 3.86^{a}
7.5	13.50 ± 1.11^{c}	6.24 ± 2.07^{c}	3.65 ± 0.64^{b}	3.05 ± 0.78^{a}	5.37 ± 1.38^{a}	70.23 ± 3.89^{a}
10.0	14.34 ± 0.92^{b}	5.60 ± 2.01^{cd}	3.30 ± 0.52^{bc}	2.68 ± 0.48^{ab}	5.96 ± 1.66^{a}	67.36 ± 4.42^{b}
12.5	15.12 ± 0.94^{a}	4.79 ± 1.58^{d}	3.09 ± 0.54^{c}	2.46 ± 0.38^{b}	5.96 ± 1.20^{a}	65.59 ± 4.49^{b}
LSD ($p = 0.05$)	0.5187	0.9369	0.5053	0.2931	0.5804	1.9463

Values are triplicate determination, Means with different letters differed significantly ($p<0.05$); dmb: Dry mass basis

The protein values were found to decrease relative to increasing strength of the steeping solution. The significant decrease in protein proportion might be associated with the cleavage of the peptide bond and uptake of molecules of water due to hydrolytic action of the complex trona salt on the plant protein. This will lead to formation of shorter chains and increase solubility (McWilliams, 2005). The reduction in protein values is not acceptable nutrition wise and might place a limit to the amount of trona necessary for steeping purpose. The highest protein was obtained for the 0.0% concentration, 9.85%, while a distant low protein value, 4.79% was observed for 12.5% steeping solution. Limiting the concentration of trona to 5.0% might be suggested, considering that the protein value associate with it did not differ from the value for 2.5% concentration at $p>0.05$.

The fat values though were significantly affected by the steeping solution concentration and had a peak value for sample from 5.0% trona strength, 4.20%. However the peak value did not differ from the value observed for 2.5% steeping solution concentration, 4.19%. The influence of trona on fat content of food material is not quite clear, though it might be suggested that trona behave as a fat stabilizer which prevents migration of fat and fat soluble components from leaching into the steeping solution. Also, the peak value at 5.0% concentration indicates a technical advantage that optimum flour quality would result when kept at such steeping strength.

The trend observed for the fibre values parallel that obtained for fat, but the 2.5% steeping solution was found to have the highest fibre, 3.14% and was followed by 5.0%, (3.08%) and 7.5% (3.08%); these however did not differ at $p>0.05$. The observed values seem to suggest that the trona solution improved the fibre content of flour when used at concentration that does not exceed 7.5%. When the trona strength is applied beyond 7.5%, witnessed a decline in fibre at 10.0% (2.68%) and 12% (2.46%).

The high values of the ash at high steeping concentrations might suggest that trona enhanced the retention of minerals in the flour. The observed ash values did not differ for the 7.5, 10.0 and 12.5% which gave 5.37, 5.96 and 5.96%, respectively.

Very minimal deviation in carbohydrate values was observed for the resultant flour as seen in Table 1. However the highest value (70.35) obtained for the 0.0% concentration, might be basis to infer that trona solution resulted in leaching out of soluble starches.

Proximate composition of three leaved yam flours as affected by boiling in various media after steeping in trona solution: The proximate values obtained by discarding the steeping solution and boiling the peeled tubers in freshly prepared trona solution and with fresh tap water as compared to boiling with spent-steep liquor is shown in Table 2. The values show that discarding the spent- steep liquor and boiling the tubers with either freshly prepared trona solution or fresh tap water did not result to significant variation in the moisture, protein, fat contents of the resultant three-leaved yam flour after boiling for 120 min at $p>0.05$. When these values are

Table 2: Mean proximate composition of flour from three-leaved yam tubers as affected by various boiling solutions

	Proximate composition (%, dmb)					
Boiling solution	Moisture	Protein	Fat	Fibre	Ash	Carbohydrate
SSL	13.57 ± 1.47^a	6.62 ± 2.06^a	3.88 ± 0.90^a	2.49 ± 0.45^b	4.82 ± 1.81^b	67.30 ± 5.04^b
FPS	13.58 ± 1.36^a	7.20 ± 2.75^a	3.57 ± 0.94^a	2.97 ± 0.71^a	4.47 ± 1.86^b	67.43 ± 5.81^b
FWT	13.52 ± 1.58^a	7.12 ± 2.07^a	3.58 ± 0.58^a	3.18 ± 0.63^a	3.55 ± 0.94^a	70.74 ± 4.16^a
LSD (p = 0.05)	0.5187	0.9369	0.5053	0.2931	0.5804	1.9463

Values are triplicate determinations, Means with different letters differed significantly ($p<0.05$), SSL: Spent-steep liquor, FPS: Freshly prepared trona solution, FWT: Fresh tap water, dmb: Dry mass basis compared with values obtained in Table 1, it might be reasoned that the actual cellular effects on the yam tissue was created by the steeping only. Significant differences ($p<0.05$) were however, obtained for the fibre, ash and the carbohydrate. A critical assessment of the various parameters showed that boiling with fresh tap water gave the best performance in terms of low mean moisture value (13.52%); highest fibre (3.55%) and carbohydrate (70.74%). Boiling with fresh tap water could be favourably considered when the need to keep residual trona in milled flour to the barest threshold is paramount.

Effects of boiling time on the proximate composition of the trifoliate yam flour cooked in trona solution: The values for moisture were found to differ significantly and increased with increasing boiling time as shown in Table 3. The highest amount of moisture was obtained for flour obtained from boiling for 120 min (14.18%) which did not differ from the sample from 90 min boiling (14.10%) while the control (0.0 min) had the least moisture value (12.41%). It is possible that boiling time enhanced diffusion rate of trona solution into the yam tissue. Another probable reason might be the presence of water of hydration in the molecular structure of trona. Thus the greater the amount diffused, the more the hydration of the resultant flour.

The highest protein value (8.61%) was observed for the control (0.0 min boiling) while the least protein value (5.73%) was recorded for 120 min boiling time. The decreasing trend of protein value might suggest that boiling led to the leaching out of soluble proteins and the intensity of leaching increased with the duration of boiling. The boiling of sliced tubers of three- leaved yam in trona affected the fat values of the resultant flours marginally. However the fat value of the 0.0 min differed from the boiled samples and only slight difference occurred at boiling for 120 min.

Peak fibre value (3.20%) was obtained for the sample from 60 min boiling duration and also the sample from 90 min boiling gave the least value 2.69% as well as that boiled for 120 min. Thus boiling for 60 min might be the best condition when fibre content is a selection criterion for yam flour.

The ash values in Table 3 show that boiling at varying time in trona solution does not affect the ash content of the resultant flour. Similarly, the carbohydrate values from boiled samples did not differ from the unboiled sample, however variation was obtained for the sample boiled for 120 min, the observed difference for 120 min boiled sample might be due to slight error in measurement.

Effects of steeping in trona solution on the functional properties of three-leaved yam flour: The pH of the flours was found to increase significantly with increase in steeping solution concentration and the sample from 12.5%, trona solution had the highest pH, 9.68 while the non

Table 3: Mean proximate composition of the flours as affected by boiling time in trona solution

	Proximate composition (%, dmb)					
Blanching time (min)	Moisture	Protein	Fat	Fibre	Ash	Carbohydrate
0	12.41±1.43^{d}	8.61±2.12^{a}	4.24±0.50^{a}	2.82±0.86^{bc}	4.03±1.19^{a}	66.72±6.77^{b}
30	13.25±1.38^{c}	7.13±1.92^{b}	3.90±0.90^{ab}	2.98±0.66^{ab}	4.29±1.38^{a}	68.14±3.50^{b}
60	13.85±1.26^{ab}	7.04±1.84^{c}	3.55±0.95^{b}	3.20±0.68^{a}	4.38±1.61^{a}	69.39±3.84^{b}
90	14.10±0.89^{a}	6.40±2.53^{cd}	3.52±0.69^{bc}	2.69±0.46^{c}	4.28±1.91^{a}	67.68±5.58^{b}
120	14.18±1.33^{a}	5.73±2.18^{d}	3.19±0.56^{c}	2.69±0.46^{c}	4.42±2.02^{a}	71.52±4.37^{a}
LSD (p = 0.05)	0.4735	0.8553	0.4613	0.2675	0.5298	1.7767

Values are triplicate determinations, Means with different letters differed significantly ($p<0.05$), dmb: Dry mass basis

Table 4: Mean physico-chemical properties of flour from three-leaved yam (tly) tubers as affected by steeping in different strengths of trona solution

Steeping solution concentration (% m/v dmb)	Physico-chemical properties pH	Swelling index SI (cm^3 cm^{-3})	WAC (mL H_2O g^{-1} dry flour)	OAC (mL Oil g^{-1} dry flour)	BVI (ppm)	TSS (%, dmb)	GPT (°C)	BPT (°C)
0.0	6.35 ± 0.23^{f}	1.79 ± 0.19^{f}	3.99 ± 0.41^{bc}	1.91 ± 0.35^{a}	190.0 ± 28.8^{e}	5.27 ± 0.74^{f}	71.3 ± 3.15^{a}	85.3 ± 3.15^{a}
2.5	8.56 ± 1.13^{e}	2.89 ± 0.43^{e}	4.65 ± 0.64^{a}	1.55 ± 0.21^{b}	216.9 ± 47.2^{c}	8.46 ± 1.71^{e}	70.4 ± 3.13^{ab}	83.8 ± 3.20^{a}
5.0	8.89 ± 1.12^{d}	3.08 ± 0.38^{d}	4.68 ± 0.82^{a}	1.59 ± 0.14^{b}	273.3 ± 49.4^{cb}	11.73 ± 2.01^{d}	69.3 ± 3.14^{ab}	81.8 ± 3.16^{b}
7.5	9.08 ± 1.04^{c}	3.31 ± 0.39^{c}	4.72 ± 0.59^{a}	1.64 ± 0.17^{b}	311.3 ± 62.8^{a}	13.82 ± 2.15^{c}	68.2 ± 2.97^{b}	79.8 ± 2.90^{c}
10.0	9.41 ± 1.00^{b}	3.48 ± 0.39^{b}	4.24 ± 0.65^{b}	2.00 ± 0.29^{a}	274.7 ± 66.1^{b}	16.09 ± 2.32^{a}	66.8 ± 2.90^{bc}	78.3 ± 2.76^{cd}
12.5	9.68 ± 1.04^{a}	3.62 ± 0.38^{a}	3.89 ± 0.41^{c}	1.41 ± 0.41^{c}	247.1 ± 40.3^{d}	15.17 ± 2.34^{b}	62.7 ± 3.98^{c}	73.4 ± 2.96^{d}
LSD (p = 0.05)	0.0854	0.0461	0.3285	0.1190	26.1627	0.3220	2.3467	1.6913

Values are triplicate determination s. Means with different letters of alphabet differed significantly ($p<0.05$), WAC: Water absorption capacity; OAC: oil absorption capacity; BVI: Blue value index; TSS: Total soluble solid; GPT: Gelatinization temperature; BPT: Boiling point temperature, dmb: Dry mass basis

trona treated sample gave the least, 6.35 (Table 4). The swelling capacity of the flours was found to increase with increase in trona strength. The flour steeped in 12.5% trona gave the highest swelling index, 3.62 cm^3 cm^{-3} while the control had 1.79 cm^3 cm^{-3}. The prominent increase in swelling capacity of the tubers steeped in trona solution might carefully be manipulated to enhance product volume for cash gain.

The Water Absorption Capacity (WAC) was found to increase significantly with increase in trona strength and reached a peak at 7.5% (4.72 mL H_2O g^{-1} dry flour) trona concentration and thereafter declined. However the mean values obtained from 2.5, 5.0 and 7.5% did not differ statistically ($p>0.05$). The implication might be that trona concentration could be limited to 2.5% when the target of modifying the flour was to increase the water absorption capacity. Contrarily to the observed behaviour for WAC, steeping in trona resulted to significant reduction in oil absorption capacity as shown in Table 4. The trend in reduction did not follow regular pattern as there was a sudden rise in OAC at steeping strength of 10% and a decline afterward. Incidentally the peak at 10% concentration (2.00 mL oil/g dry flour) did not differ from the untreated sample 1.91 mL oil g^{-1} dry flour.

The Blue Value Index (BVI) was found to increase with increase in trona concentration but a peak occurred at 7.5%, 311 ppm and declined thereafter. The observed increases in BVI represented the extent of damage caused by the application of trona on the native starches. Also, the Total Soluble Solid (TSS) was found to increase with increase in concentration of trona. However the highest %TSS was observed for sample from 10% steeping solution strength (16.09%).

On the other hand, treatment with trona remarkably reduced the Gelatinization Temperature (GT) and the boiling temperature (BPT). The least GT and BPT were observed for sample from 12.5% concentration (62.7 and 73.4°C, respectively). The reduction in both GT and BPT are the technical reasons for the application of trona in cooking three-leaved yam in Eastern part of Nigeria.

Effects of various steeping solution on the functional properties of three-leaved yam flour: The influence of the various steeping solution on the physicochemical properties of the flour revealed that when cooked in various solutions, the observed values differed significantly at $p<0.05$ (Table 5). When fresh tap water is used for boiling of the tubers, marginal reduction in the pH, 9.00 occurred and cooking in fresh trona tilted the pH towards the alkaline pH which eventually was the highest, pH, 9.65.

Table 5: Mean physico-chemical properties of flour from Three-Leaved Yam (TLY) tubers as affected by boiling in various in solutions

Nature of blanching solution	Physico-chemical properties pH	Swelling index SI ($cm^3\ cm^{-3}$)	WAC (mL H_2O g^{-1} dry flour)	OAC (mL Oil g^{-1} dry flour)	BVI (ppm)	TSS (%)	GPT (°C)	BPT(°C)
SSL	9.35±1.64^b	3.08±0.70^a	4.06±0.53^b	1.69±0.37^a	280.9±70.8^a	11.99±4.31^b	68.1±4.16^a	80.4±4.79^b
FPS	9.65±1.28^a	2.98±0.65^c	4.84±0.67^a	1.68±0.34^b	256.4±58.8^b	12.64±4.39^a	66.7±4.15^b	78.9±4.87^c
FWT	9.00±0.82^c	3.03±0.76^b	4.17±0.60^b	1.68±0.33^b	219.3±4.59^c	10.64±3.93^c	69.6±4.21^a	81.9±4.84^a
LSD (p = 0.05)	0.0604	0.0326	0.2323	0.0841	18.4998	0.2277	1.6594	1.2002

Values are triplicate determinations, Means with different letters differed significantly ($p<0.05$), SSL: Spent-steep liquor, FPS: Freshly prepared trona solution, FWT: Fresh tap water, WAC: Water absorption capacity, OAC: Oil absorption capacity, BVI: Blue value index, TSS: Total soluble solid, GPT: Gelatinization temperature, BPT: Boiling point temperature

The observed values for the swelling capacity showed that the flour obtained when boiled with the steep liquor gave the highest value, 3.08 which differed from rests.

On the other hand Freshly Prepared Solution (FPS), was found to give the highest water absorption capacity, 4.84 mL H_2O) g^{-1} dry flour, followed by the sample from fresh tap water. On the contrary the oil absorption decreased significantly $p<0.05$, with FPS recording 1.68 mL Oil g^{-1} dry flour which invariably did not differ from the value obtained from FWT, 1.68 mL g oil g^{-1} dry flour.

Changing the steeping solution remarkably decreased the Oil Absorption Capacity (OAC). The highest OAC was recorded for the sample boiled with the steeped liquor 1.69 mL oil g^{-1} dry flour while the samples from freshly prepared trona solution (FPS, 1.68 mL oil/ g dry flour) did not differ from the sample boiled in FWT. Oil absorption capacity may also have been due to higher protein contents of germinated sample. Anusuya-Devi and Venkataraman (1984) and Eke and Akobundu (1993) had associated oil absorption capacity to ability of protein fractions to bind fats.

Boiling in Steeped Liquor (SSL) gave the highest value for the Blue Value Index (BVI), 280.9 ppm which is followed by FPS, 256.4 ppm and FWT gave the least, 219.3 ppm.

When the tubers were boiled in freshly prepared trona solution, it had the highest effect on native starch; the %TSS of the resultant flour was higher than others produced from blanching in FWT (10.64%) and SSL (11.99%).

The FPS was found to decrease the Gelatinization Temperature (GPT), 66.7°C and the boiling point (BPT), 78.9°C than other flour counterparts. The variation in the gelling properties of different legume flours is associated with the relative ratio of different constituents like proteins, carbohydrates and liquids that make up the legume flours which seem to indicate that interaction between these components may have significant role in their functional properties (Deshpande *et al*., 1982; Nwanekezi *et al*., 2010).

Effects of boiling time on the functional properties of flour boiled in trona solution: When the tubers were boiled in trona solution at varying temperature, the observed effects on the physicochemical properties revealed differences at $p<0.05$ as shown in Table 6.

The pH values obtained show that the 0.0% (control) had a value in the acid regime, 6.40 while the rest of the flour were in the alkaline region and that pH of the flours also increased with increase in boiling time. It might be suggested that diffusion of the trona into tissue of the blanched tubers was intensified as the time of boiling elapsed.

A gradual but significant increase in the swelling capacity (SI) of the flours occurred as a result of the boiling treatments, which the highest swelling capacity (3.46 $cm^3\ cm^{-3}$) was obtained for

Table 6: Mean Physico-chemical properties of flour from Three-Leaved Yam (TLY) tubers as affected by boiling time in trona solution

Boiling time (min)	Physico-chemical properties							
	pH	Swelling index, SI (cm^{-3} cm^{-3})	WAC (mL H_2O g^{-1} dry flour)	OAC (mL Oil g^{-1} dry flour)	BVI (ppm)	TSS (%)	GPT (°C)	BPT (°C)
0	6.40 ± 1.17^{e}	2.54 ± 0.53^{e}	4.24 ± 0.64^{a}	2.10 ± 0.41^{a}	228.0 ± 35.5^{c}	9.49 ± 3.13^{e}	72.8 ± 2.79^{a}	84.9 ± 4.19^{a}
30	8.26 ± 1.24^{d}	2.80 ± 0.55^{d}	4.37 ± 0.56^{ab}	1.66 ± 0.24^{b}	249.3 ± 57.7^{bc}	10.59 ± 3.63^{d}	69.6 ± 2.99^{b}	81.9 ± 4.12^{b}
60	8.65 ± 1.35^{c}	3.09 ± 0.64^{c}	4.66 ± 0.79^{b}	1.53 ± 0.22^{c}	254.4 ± 64.4^{a}	11.90 ± 4.06^{c}	67.7 ± 3.19^{bc}	80.0 ± 4.22^{b}
90	8.98 ± 1.50^{b}	3.27 ± 0.69^{b}	4.21 ± 0.70^{a}	1.59 ± 0.23^{bc}	268.1 ± 60.4^{a}	12.92 ± 4.33^{b}	66.2 ± 3.26^{bc}	78.5 ± 4.11^{c}
120	9.42 ± 1.66^{a}	3.46 ± 0.70^{a}	4.32 ± 0.64^{a}	1.53 ± 0.22^{c}	261.2 ± 86.8^{a}	13.88 ± 4.66^{a}	64.3 ± 3.25^{c}	76.8 ± 4.00^{d}
LSD (p = 0.05)	0.1480	0.0421	0.2998	0.1086	23.8832	0.2940	2.1423	1.5494

Values are triplicate determination, Means with different letters differed significantly ($p<0.05$), WAC: Water absorption capacity, OAC: Oil absorption capacity, BVI: Blue value index, TSS: Total soluble solid, GPT: Gelatinization temperature, BPT: Boiling point temperature

sample blanched for 120 min, while the least value (2.54 cm^3 cm^{-3}) was recorded for 0.0 min sample. The Water Absorption Capacity (WAC) was found to increase with boiling time and reached a peak at 60 min blanching time and decreased thereafter. Suggested implication of the peak at 60 min boiling might be that it is the appropriate boiling duration which means exceeding this time amounts to waste in terms of energy and quality of product. Water absorption capacity of flours is influenced by the degree of disintegration of native starch granules (Ayernor, 1985). Suggesting that undamaged starches have low potential absorption capacities. The water absorption capacity of flour enables the processor to add more water during food preparation which enhances profitability; and also improves handling characteristics. It maintains the freshness of bread, cakes and sausage (Akobundu *et al*., 1982). The water absorption capacity of legume protein is affected by heat treatment which causes dissociation of the native proteins into sub – units that have more water-binding sites than oligomeric proteins (Nwanekezi *et al*., 1994).

Boiling in trona solution also caused remarkable decrease in Oil Absorption Capacity (OAC) as the blanching time increased. The unboiled sample had superior value for OAC, 2.10 mL oil g^{-1} dry flour. Again, among the boiled samples the flour from 30 min boiling (1.69 mL oil g^{-1} dry flour) gave better value than the rest.

On the other hand, there were increases in the Blue Value Index (BVI) as the boiling time increased. The trend is expected as heating caused more rearrangement in the native starches. Similar increasing trend was obtained for the Total Soluble Solids (TSS) which differed significantly with the resultant flour from 120 min boiling having the highest value, 13.88% while the unboiled sample had the least, 9.49%.

Boiling in trona solution resulted in significant decrease in both the gelatinization temperature and boiling point of the samples. Onwueme (1978) associated gelling ability to the percentage of damaged amylose fraction to amylopectin ratio of the starch. These are the major reasons for employing trona in the traditional cooking of trifoliate tubers in the eastern State of Nigeria.

CONCLUSION

The study appraised the various pre treatments with trona solution (steeping in trona concentration, boiling in solutions of diverse nature and boiling in varying concentration over time) which revealed modifications of the resultant trifoliate yam flours:

- The modification of the flour steeped in trona solution resulted from its ability to open up the cell structure of the plant tissue for absorption of moisture which intensified as the steeping concentration increases; incidentally the absorbed water became difficult to be removed by conventional drying
- Pre treatment of cut tubers in trona solubilised soluble proteins and caused reductions in protein content which intensified as the steeping concentration increased
- The resultant flour from trona solution pre treatment was in the alkaline range of pH which might not enhance the quality of flour when stored or used in some food preparation
- The trona pre treatments at various concentrations were effective in reducing the cooking time; this was evident as the gelatinization and boiling point were lowered. Hence the technical reason for the use of trona as steeping or cooking medium for trifoliate yam is because it reduces the cooking time

REFERENCES

AOAC, 1990. Official Methods of Analysis. 13th Edn., Association of Official Analytical Chemists, Arlington, pp: 222-225.

Abbey, B.W. and G.O. Ibeh, 1988. Functional properties of raw and heat processed cowpea (*Vigna unguiculata* Walp) flour. J. Food Sci., 53: 1775-1777.

Akobundu, E.N.T., J.P. Cherry and J.G. Simmons, 1982. Chemical, functional and nutritional properties of egusi (*Colocythis citrullus* L.) seed protein products. J. Food Sci., 47: 829-835.

Alozie, Y., M.I. Akpanabiatu, E.U. Eyong, I.B. Umoh and G. Alozie, 2009. Amino acid composition of *Dioscorea dumetorum* varieties. Pak. J. Nutr., 8: 103-105.

Anusuya-Devi, M. and L.V. Venkataraman, 1984. Functional properties of protein products of mass cultivated blue-green alga (*Spirulina platensis*). J. Food Sci., 49: 24-27.

Ayernor, G.S., 1985. The Yam (Dioscorea) Starches. In: Advances in Yam Research: A Biochemistry and Technology of the Yam Tuber, Osuji, J. (Ed.). ASUT., Enugu, Nigeria, ISBN: 9781561998, pp: 77-88.

Coursey, D.G. and C.E.M. Ferber, 1979. Processing of Yam. In: Small-Scale Processing and Storage of Tropical Root Crops, Plucknett, D.L. (Ed.). Westview Press, Builder, Colorado, pp: 189.

Degras, L., 1993. The Yam: A Tropical Root Crop. Macmillan Press Ltd., London, Basingstoke, ISBN: 9780333574560, pp: 29-41.

Deshpande, S.S., S.K. Sathe, D.K. Salunkhe and D.P. Comforth, 1982. Effects of dehulling on phytic acid, polyphenols and enzyme inhibitors of dry beans (*Phaseolus vulgaris*). J. Food Sci., 47: 1846-1850.

Eke, O.S. and E.N.T. Akobundu, 1993. Functional properties of African yam bean (*Sphenostylis stenocarpa*) seed flour as affected by processing. Food Chem., 48: 337-340.

Faboya, O.O.P. and A.A. Asagbara, 1990. The physic chemical properties of starches from some Nigerian cultivars of white yam (*Dioscorea rotundata poir*). Trop. Sci., 30: 51-57.

Kawabata, A., S. Sawayama, N. Nagashima, R.R. del Rosario and M. Nakamara, 1981. Some Physico-chemical properties of starches from cassava arrow root and sago. J. Japan Soc. Starch Sci., 31: 224-232.

McWilliams, M., 2005. Foods Experimental Perspectives. 4th Edn., Pearson Prentice-Hall, Inc., New Jersey, USA., pp: 301-311.

Medova, G.N., T.L. Mbome, I. Agbor-Egbe and C.N.F. Mbefung, 2005. Study of the hard-to-cook property of stored yam tubers (*Dioscorea co dumeturun*) and some determining biochemical factors food determining biochemical factors. Food Res. Int., 28: 143-149.

Mensah, E.O. and S. Sefa-Dedeh, 1991. Traditional food processing technology and high protein food production. Food Nutr. Bull., 13: 82-82.

Nkala, D., S. Sibanda, P. Tomasik and M. Palasinski, 1994. Isolation and properties of starch from wild yam from Zimbabwe. Starch, 46: 85-88.

Nwanekezi, E.C., C.I. Owuamanam, N.C. Ihediohanma and J.O. Iwouno, 2010. Functional, particle size and sorption isotherm of cocoyam cormel flours. Pak. J. Nutr., 9: 973-979.

Nwanekezi, E.C., O.G.C. Alawuba and C.I. Owuamanam, 1994. Functional properties of raw and heat processed African yam bean (*Sphenostilis stenocarpa*) and bambara groundnut (*Voandzeia subterranea*) flours. J. Food Sci. Technol., 31: 179-201.

Olorunda, A.O., 1979. Storage and Processing of Some Nigeria Root Crops. In: Small-Scale Processing and Storage of Tropical Root Crops, Plucknett, D.L. (Ed.). Westview Press, Boulder, Colorado, pp: 95.

Onuegbu, N.C., C.I. Iwuoha, C.I. Owuamanam and N.C. Ihediohanma, 2011. Effects of boiling solution (trona) concentration and time on the proximate composition and physico-chemical propterties of flour from three-leaved yam (*Dioscorea dumetorum* pax) tubers. Afr. J. Food Sci., 5: 1-5.

Onwueme, I.C., 1978. The Tropical Tuber Crops, Yam, Cassava, Sweet Potato and Cocoyam. John Wiley and Sons, New York, Brisbane and Toronto, pp: 199-227.

Onwuka, G.I., 2005. Food Analysis and Instrumentation: Theory and Practice. Naphthali Print, Lagos, Nigeria.

Rockland, L.B. and G.F. Stewart, 1981. Water Activity: Influence on Food Quality. Academic Press, New York, USA., pp: 46-47.

SAS, 2000. SAS/STAT User's Guide. Version 8, Vol. 1-3, SAS Institute, Cary, NC.

Udensi, F.A. and J.O. Onuora, 1992. Chemical and functional properties of some Soya bean flour in the Nigerian market. Proceedings of the 16th Annual Conference of Nigeria Institute of food Science and Technology, October 26-30, 1992, Enugu, Nigeria, pages: 8.

Ukpabi, U.J. and C. Ndimele, 1990. Evaluation of the quality of gari produced in imo state. Niger. Food J., 8: 105-110.

Ukpabi, U.J., 2010. Farmstead bread making potential of lesser yam (*Dioscorea esculanta*) flour in Nigeria. Aust. J. Crop Sci., 4: 68-73.

Uzoma, A. and C.M. Osuji, 2004. Effect of Alkali and alkali salts treatments on the aqueous dispersion of reconstituted soy flour. Proceedings of the 28th Annual Conference of Nigeria Institute of Food Science and Technology, October 14, 2004, Ibadan, Nigeria.