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Production and quality evaluation of pre-gelatinized fermented breakfast food produced from edible trifoliate yam (*Dioscorea dumetorum*) using intermediate technologies in Nigeria

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Abstract

Wholesome tubers of edible trifoliate yam (*Dioscorea dumetorum*) cultivar were used to produce innovative dehydrated pre-gelatinized fermented breakfast food (in batches) by employing local intermediate technologies in Nigeria. The granular trifoliate yam product had a cream-light yellowish brown colour and a packed bulk density of 0.46g/cm³. The water and oil absorption capacities were 40g/g and 1.71g/g respectively. Aggregate size analysis showed that all the product particles were <4mm and >0.063mm, with 76% of them between 0.5mm and 2mm. Beabender amylograph reading with 15% suspension (in water) of the product gave a maximum gelatinization viscosity of 1,740 A.U. and gelatinization temperature of 85.6-91.8°C, as opposed to 1,150 A.U. (maximum viscosity) and 83.9-87.6°C (gelatinization temperature) of 15% suspension of starch from the trifoliate yam raw material or tuber. Cooking time of the product (in boiled water) was 1.83 minutes. The breakfast food (from trifoliate yam) had a proximate composition of 5.05% moisture, 1.20% ash, 3.63% fibre, 11.12% protein, 0.68% ether extract, 78.32% carbohydrates and a caloric value of 1.52MJ/100g. Ten percent suspension of the product in distilled water had a pH of 4.2. The observed pathogen-free packaged yam breakfast product could be considered as an innovative pilot plant food. Sensory evaluation of breakfast porridge, made with the particulate product, showed that the assembled 30 semi-trained panelists liked the colour, taste, flavour and mouth-feel of the meal.

1. Introduction

Trifoliate yam or three-leafed yam (*Dioscorea dumetorum* Pax) belongs to the genus *Dioscorea* and family *Dioscoreaceae* (Onwueme, 1978; Bai and Ekanayake, 1998). The starchy tubers may be single but are usually produced in clusters, in a stand of the plant. Trifoliate yam is also known as cluster yam because of the nature of the tubers (Kay, 1987). Some scientists and writers also refer to *D. dumetorum* as bitter yam because of the bitterness of the tubers of the wild type (and few cultivated landraces) in Africa. Traditionally, trifoliate yam is eaten after boiling the unpeeled tuber to softness (Kay,

1987). Unlike in Nigeria where white guinea yam (*Dioscorea rotundata*) is highly cherished and produced (Okoli, 1993; Orkwor and Ikeorgu, 2010), trifoliate yam is the preferred food yam in Cameroun, with regards to palatability and tuber yield in the field (Bell and Favier, 1981; Lyonga and Ambe, 1984; Numfor and Lyonga, 1987). Nutritionally, trifoliate yam is considered superior to other food yams in Africa in terms of protein content. The protein content of the tuber on dry matter basis is 11-13% (Oyenuga, 1968; Onwueme, 1978; Bell and Favier, 1981; Owuamanam *et al.*, 2013). This protein content is comparable to those of cereals (UNECA, 1985).

Breakfast cereals found in the industrialized countries include cornflakes (from maize), wheat flakes, rice flakes, wheat and oat rolls, and quick cooking pre-gelatinized oat meals (Kulp and Ponte, 2000). These breakfast cereals, which are usually consumed with milk, need high technology equipments and operations for their respective industrial production (Proudlove, 1990; Kulp and Ponte, 2000). Pregelatinization of starchy staples allows for relatively short cooking time for the breakfast (Marshal, 1995). In West Africa, the storable pre-gelatinized granular cassava (*Manihot esculenta*) gari (Ukpabi and Dafe, 1999) is sometimes used in the preparation of the morning meal or breakfast (Dovlo *et al.*, 1985; Kordylas, 1990). Here, the fermented cassava gari, milk and sugar are used for breakfast. Gari is also soaked in cold water to form a porridge, which is sweetened with sugar and eaten after the addition of evaporated milk.

Trifoliate yams are now less utilized as food because of the tubers' long-cooking time, non-cookability of the stored bruised tubers, urbanization with attendant preference for easy-to-prepare foods and changing eating habits (Numfor and Lyonga, 1987; Medowa *et al.*, 2008; Abiodun *et al.*, 2009). There is, therefore, every need to investigate the feasibility of producing easy-to-cook, energy rich, proteinous breakfast food from the trifoliate yam's starchy tuber. This is in consonance with the suggestions of FAO (1987) and Achinewhu (1996) that indigenous plants with good nutritional values should not be allowed to give way to imported processed plant food products. The need to give more value to trifoliate yam and make it available "all year round", through processing, require necessary attention. In view of the dearth of entrepreneurs involved in large scale industrial food processing of local roots and tubers, it therefore becomes necessary to use equipment or technologies that could be adapted by numerous small/medium scale food processors – to convert edible trifoliate yams into easy-to-prepare dry breakfast food for teeming African urban dwellers, and even rural dwellers with changed eating habits.

Successful production of an innovative breakfast food with this yam variety, will not only encourage the cultivation of the crop, but will also enhance the economic value of the crop at the long run – as the dry fermented gari has done to cassava. Interestingly, Medowa *et al.* (2008) also showed that fermentation could have positive effect on some quality

characteristics of trifoliate yam. Therefore, the aim of this study is to produce an acceptable, storable fermented innovative breakfast food from the tubers of the edible variety of *D. dumetorum*, employing technologies that can be adopted by small to medium scale food processors.

2. Materials and Methods

2.1. Sources of Experimental Yam Tubers and Chemicals

The tubers of the experimental trifoliate yam cultivar (Figure 1) were randomly collected from the Yam Barn of National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria (05° 29' N Latitude, 07° 33' E Longitude). The names for the experimental trifoliate yam landrace or cultivar in the predominant local Igbo (Ibo) dialects include: *Una* (or *Ona/Onu*) *Obiaraohuru*, *Una obiaraofuru*, *Una Ohafia* and *Una-Uzuakoli*. The analytical chemicals and reagents used in this study were manufactured by BDH (British Drug Houses), Poole, England.



Figure 1. Photograph of a cluster of the experimental trifoliate yam tubers (in the middle).

2.2. Production of the Breakfast Food

Figure 2 shows the flowchart for the production of the breakfast food from the experimental trifoliate yam tubers. Pre-processing trials were done to standardize the fermentation time and dewatering rate. The breakfast food production was done in batches of 50kg tubers with modified local cassava gari processing methods (Ukpabi and Dafe, 1999; Adekanye *et al.*, 2013) and equipment/devices/tools (Ihekeronye, 1999, Adekanye *et al.*, 2013).

Wholesome tubers of trifoliate yam were used as raw-materials, while peeling was done manually with sharp kitchen knives. The peeled tubers were collected in large basins and washed with clean tap water. The washed peeled tubers were grated with washed RAIDS diesel powered, mechanical grater (Rural Agro-Industrial Development Scheme, Ibadan, Nigeria), used for gari processing. The yam pulp was put in a double-layered 50kg rice plastic sack (Caprice, Bangkok, Thailand). The tightly woven, double layered polypropylene sack had its mouth twisted and tied up (with rope) for simultaneous dewatering and fermentation that lasted for 24 hours. A screw press was used to reduce the moisture content of the yam pulp (in the sack) to about 50%

in the first hour of fermentation, and about 40% at the end of fermentation.

The resulting fermented caked trifoliate yam mash was manually broken, pulverized and sifted with a 4mm sieve. 1.5kg of the sieved yam mash was then toasted in a firewood heated cast-iron gari-processing or *garification* pan (17cm deep and 55cm in diameter) in batches. The toasting was done in each batch by using a calabash section (about 15cm x 20cm) to constantly stir the dewatered sieved mash against the hot surface of the pan until gelatinized grains were formed. The toasting process was stopped when the gelatinized granular breakfast food started making rusting noise. The breakfast food was quickly removed from the pan at this stage to avoid burning.

The breakfast food was allowed to cool in a well-ventilated room (with fly proof) to ambient room temperature (29-32°C). Sterilized steel ladles were used to put 50g breakfast food portions into 0.75mm thick low density, polyethylene (LDPE) bags. The transparent LDPE bags were heat sealed with a sealing machine (SP-200H Double Leopard).

Top loading balances (Salter Model 250 and Sartorius LC 120IS) were used to weigh the material losses and yields during the production of the breakfast food. The weighings were done in sextuplicate and recorded as percentage of the original raw materials (trifoliate yam tubers). Furthermore, the packaged breakfast food samples were stored for up to 60 weeks at ambient room temperature (24-32°C), away from direct sunlight (in a file cabinet).

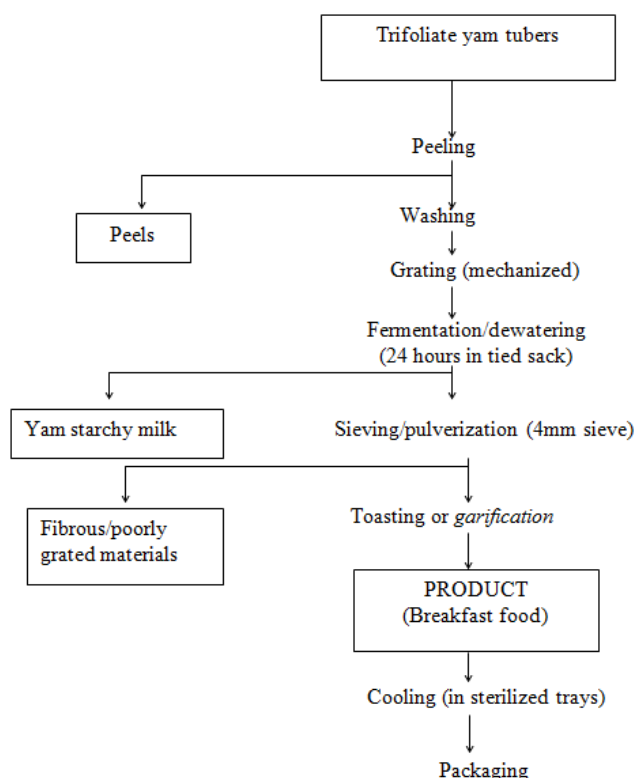


Figure 2. Flow-chart for the production of the breakfast food from trifoliate yam tubers.

2.3. Yam Tuber Processing Data

Data considered necessary for large scale automated mechanical production of the pre-gelatinized breakfast food were collected as follows:

2.3.1. Tuber Density

The trifoliate yam tuber's density (mass/volume) was got by weighing randomly selected tubers with the top loading balance (Sartorius LC120IS), and getting the tuber volume by water displacement technique in a 2-litre measuring cylinder. The difference between the volume of the water before and after putting the trifoliate yam tuber in the cylinder was recorded as the tuber volume. The density was calculated as mass/volume.

2.3.2. Processing Temperatures

A thermometer was used to measure the temperature of the following: trifoliate yam mash before toasting or *garification*, the heated cast-iron pan (base and top of the toasting surface) before and during the toasting or *garification* process, and the yam mash during and after toasting or *garification*.

2.3.3. Heat Processing Periods

A stopwatch was used to time the periods for the following: toasting or *garification* of each batch of 1.5kg dewatered fermented yam mash, duration of each stirring operation, and intervals between the stirring periods.

2.3.4. Processing Dimensions of Dewatered Mash

A ruler was used to measure the varied thickness or depth of the yam mash layer on the toasting surface of the *garification* pan.

2.4. Determination of Physical and Functional Properties

2.4.1. Particle Size Distribution

Aggregate sizes of the granular breakfast food were determined with Endecotts sieve shaker (model 2MK/II, Endecotts, London, England) and sieves. The apertures of the experimental test sieves were 4mm, 3.35mm, 2mm, 1mm, 0.5mm, 250µm, 63µm, 53µm and 0µm (collecting pan). The sieves were serially packed in the shaker with collecting pan (with no aperture) at the bottom and the sieve with the largest aperture size on top. 20g sample of well-mixed breakfast food was spread on the topmost sieve before switching on the shaker. Sample distributions in the experimental sieves were calculated as percentages of the original weight.

2.4.2 Swelling Index

Swelling index was calculated using the method of Ukpabi and Dafe (1999). Exactly 10g of the breakfast food was weighed into a 100ml measuring cylinder, leveled and the product volume noted. Distilled water was added to half of the cylinder, and the product inside allowed to stand for 1 hour. The final volume of the swollen product was then recorded, and swelling index was calculated as the ratio of the final volume to initial volume, that is,

$$S_i = V_2/V_1$$

where S_i is swelling index, V_1 is initial volume and V_2 is final volume.

The swelling index of the product was determined at water temperature of 26°C.

2.4.3. Bulk Density

Bulk density was calculated as weight of sample per unit volume of sample (g/ml). Previously weighed or tared 100ml measuring cylinder was gently filled with 50g of the product for the loose bulk density determination. The bottom of the cylinder was gently tapped on a laboratory bench several times until a constant volume was obtained. This final volume was then used for the calculation of the packed bulk density.

2.4.4. Emulsion Capacity

The method described by Yasumatsu *et al.*, (1972) was used to determine the emulsion capacity of the breakfast food. Exactly 1.8g of the sample was dispersed in 25ml distilled water, and 25ml vegetable oil (cotton seed oil) with density of 0.901 – was added to the sample. The 50ml mixture was emulsified at high speed using a blender (Moulinex Mill 2) for one minute. The emulsion was then filled into a calibrated centrifuge tube and centrifuged at 1,600 rpm for 5 minutes at 29°C. The volume of oil separated from the mixture after reaching the emulsion break point was read directly from the tube. Emulsion capacity was expressed as the amount of oil emulsified and held per gram of sample.

2.4.5. Water Absorption Capacity

Water absorption capacity of the product was determined using the method of Abbey and Ibeh (1988). One gramme of the sample was mixed with 10ml distilled water for 30 seconds in a mixer (vari-whirl) set at high speed. The sample was then allowed to stand for 30 minutes at prevailing room temperature (28.5-29.5°C) and centrifuged at 5,000 x G for 30 minutes. The volume of supernatant in a 10ml measuring cylinder was noted. The amount of water absorbed (total minus free) was multiplied by its density and expressed as the grams of water per gram sample.

2.4.6. Oil Absorption Capacity

The method of Abbey and Ibeh (1988) was also used to determine the oil absorption capacity of the product. Exactly 1g sample was mixed for 30 seconds with 10ml cotton seed oil and allowed to stand at prevailing room temperature (28-30°C) for 30 minutes and centrifuged at 5,000 x G for 30 minutes. The volume of the supernatant in a 10ml graduated measuring cylinder was noted. The amount of oil absorbed (or retained) was multiplied by its density and expressed as the gram of oil absorbed (or retained) per gram of sample. The oil absorption capacity can be mathematically expressed as:

$$d(x-y)/w$$

where

d = density of the oil

x = volume of oil used (10ml)

y = volume of oily supernatant

w = weight of the product (1g)

2.4.7. Colour

Colour of the trifoliate yam breakfast food particles was determined visually.

2.5. Comparative Brabender Amylograph Determinations

Brabender amylograph, model PT 100 (identification number 8001 45), with electronic temperature controller (identification number 6 80 026) (Brabender, Duisburg Germany), was used to determine the gelatinization temperatures and paste viscosity of the trifoliate yam breakfast food, cassava gari, powdered trifoliate yam breakfast food, powdered cassava gari, trifoliate yam starch, cassava starch, trifoliate yam flour, fermented trifoliate yam flour and wheat flour pastes. The amylograph determinations of the wheat and cassava products were done in order to provide information for possible alternative uses of the trifoliate yam breakfast food.

The gari for the experiment was obtained from the Gari Processing Unit, National Root Crops Research Institute (NRCRI), Umudike, Nigeria while the trifoliate yam flours were produced at Umudike Nigeria. The wheat flour was obtained from Home Economics Department, Michael Okpara University of Agriculture, Umudike, while the trifoliate yam starch and cassava starch were produced from their respective tubers by peeling, washing, grating, sieving with copious amount of clean water (using 100 microns sieve), sedimentation and oven drying to constant weight at 55°C. Moulinex coffee blender was used to convert the caked trifoliate yam and cassava starches, cassava gari and the trifoliate yam breakfast food into powders. The trifoliate yam cultivar used for the production of the breakfast food was also used for the production of the trifoliate yam starch and flours.

The rapid operational mode in the instrument manual of the Brabender amylograph (Brabender, 1993) was used for amylograph determinations. Distilled water was used to get 530g lump free (15% w/w dry-solid basis) homogenous suspension sample in the mixing bowl. The suspension was then poured into the amylograph bowl. This pre-mixing procedure took place in ≤ 2 minutes. The amylograph bowl was put in the machine with the measuring sensor correctly inserted and coupled to the measuring shaft. The instrument head was lowered with the hand lever. During the test run, the instrument was switched off after the gelatinization peak had been reached. For the tuber samples, the curve flow was off-set by placing additional weight, supplied with the equipment (Brabender, 1989). The minimum and maximum gelatinization temperatures were read off from digitalized temperature dial, while the maximum paste viscosity was got from the amylogram on the graduated paper chart (supplied with the equipment).

2.6. Chemical Determinations

2.6.1. Proximate Composition

The proximate composition (moisture, protein, lipid, fibre, ash, carbohydrate) of the breakfast food was determined according to the standard procedures (AOAC, 1990). Crude protein was expressed as % nitrogen x 6.25, while carbohydrate content was determined by difference.

2.6.2. Caloric Value

The caloric value of the breakfast food was obtained using the method outlined by Onyeike *et al.* (1995). The crude protein, fat (lipid), and carbohydrate contents were multiplied by 4, 9 and 4 (Atwater factors) respectively. The caloric value was then calculated as the sum of the products and expressed as Calories or kilocalories.

2.6.3. pH and Total Titratable Acidity of the Breakfast Food

A pH meter (Hanna, model HI 9050) was used to determine the pH of 10% (w/v) suspension of the trifoliate yam breakfast food in distilled water. The suspension was stirred for 30 minutes before the pH reading at room temperature (28-29°C). The pH of the fermented dewatered yam mash (before heat processing) was similarly determined. Titratable acidity was determined by acid-base titration. Ten gramme sample was weighed into a conical flask with 200ml of distilled water. The suspension was stirred and allowed to stand for 30 minute with occasional stirring. The mixture was then filtered and the final volume of the filtrate was measured and recorded. 20ml filtrate was titrated with 0.5N sodium hydroxide solution to a pink end-point with phenolphthaleine. Total titratable acidity was calculated (as lactic acid) as follows:

$$\% \text{ Total titratable acidity (TTA)} = \frac{0.5 \times \text{Titre} \times 90 \times V_f}{20 \times 1000 \times W_s} \times \frac{100}{1}$$

where

W_s = weight of sample

V_f = volume of filtrate

Lactic acid ($\text{CH}_3\text{CHOH COOH}$) has a molecular weight of 90. The titre used for the calculation was the titre of the sample minus titre of blank (distilled water).

2.7. Microbiological Analyses

In order to study the microbial properties of the fermented food product (as related to food safety), standard methods (ICMSF, 1988; Oxoid, 1990; Bainbridge *et al.*, 1996) were used for the microbiological analysis of representative samples of the breakfast food. Citrate and Indole tests were used to check for the presence of faecal coliform bacteria in the experimental samples. MacConkey Agar (for coliforms) and Potato Dextrose Agar (PDA) (for fungi) were used to check for pathogenic microbes in the stored packaged dehydrated breakfast food. This monitoring was done every 12 weeks for 60 weeks.

2.8. Cooking (Boiling) Time Determination

Boiling in water over the “medium burner” of Ignis gas cooker was used to determine the cooking (boiling) time of the trifoliate yam breakfast food. A Breitling stopwatch was used to monitor the time it took 315g trifoliate yam breakfast food poured into 1,750 cm³ boiled water (in a Tower aluminum pot) to cook to complete gelatinization and ‘doneness’.

2.9. Sensory Analysis

Procedures explained by Jellinek (1985) and Bainbridge *et al.* (1996) were used to do the sensory evaluation of the trifoliate yam breakfast food and the product stored for about one year (60 weeks). Thirty (30) assessors (semi-trained panelists) drawn from the staff of National Root Crops Research Institute, Umudike and students of Michael Okpara University of Agriculture, Umudike were used for the sensory evaluation. Gender consideration influenced the choosing of 15 males and 15 females, for the panel. The assessors were trained to score independently and objectively (without bias) with a pre-trial scoring test. A seven-point Hedonic scale was used to score the samples for colour, taste, flavour, mouth-feel and general acceptability after their reconstitution in water, cooking (for 110 seconds) and addition of milk and sugar as shown in Table 1. The porridge from each breakfast food sample was served warm to the assessors. Liquid milk was made from Peak full-cream powdered milk by adding one part of the Peak powdered milk to 3 parts (by volume) of clean water. Clean water was also given to the assessors to rinse their mouths after each testing. Each test panelist was also requested to comment on the breakfast food porridge. In the scoring of the sensory characteristics, with the 7-point Hedonic scale, 6 = like extremely, 5 = like highly, 4 = like, 3 = neither like nor dislike, 2 = dislike, 1 = dislike highly and 0 = dislike extremely.

Table 1. Ingredients for the preparation of the experimental trifoliate yam breakfast porridge.

Ingredients	Quantity
Trifoliate yam product	90g
Water	500 ml
Milk	300 ml
Sugar (sucrose)	32g (6 cubes)

2.10. Statistical Analysis

Statistics Analysis System (SAS)/PC software (License site 0022206002 of International Institute of Tropical Agriculture, Ibadan) was used for mean separations and standard deviations of data. The copyright (1989-1996) belongs to SAS Institute Incorporated, Cary, North Carolina, U.S.A..

3. Results and Discussion

The photograph of the pre-gelatinized granular breakfast food produced after one-day fermentation and thermal

processing of the dewatered trifoliate yam mash or pulp is shown in Figure 3. There was observed browning (in the bagged pulp) from the outside (in contact with the atmosphere) to the inside, after 24 hours of fermentation of the yam pulp. This browning further intensified during the toasting or garification process. Oxidative browning in yam processing is known to be catalyzed by phenolases (Anosike and Ikediobi, 1985). These enzymes, in the presence of oxygen, catalyze the polymerization of some phenolics into the darkish or brownish polyphenols (Okaka and Okaka, 2001). Temperatures above 70°C are known to denature the yam polyphenol oxidase (Anosike and Ikediobi, 1985; Ozo and Caygill, 1986), and Okaka and Okechukwu (1993) also observed that Maillard reactions in yam processing take place only under alkaline conditions. Amongst the major Nigerian yam species (*Dioscorea rotundata*, *Dioscorea alata*, *Dioscorea cayenensis*, *Dioscorea dumetorum*, *Dioscorea bulbifera*), *D. dumetorum* has the lowest polyphenol oxidase activity (Anosike and Ikediobi, 1985; Ozo and Caygill, 1986). Anosike and Ikediobi (1985) noted that polyphenol oxidase activity level and phenolic content of the yam are related to the level of enzymatic browning in the processed yam product. They also noted that cell disruption of the fresh yam tuber tissue (during processing) is required for the cellular compartmentalized polyphenol oxidase and phenolics to have contact with each other and atmospheric oxygen. Caramelization has also been noticed during thermal processing of yams (Okaka and Okechukwu, 1993).

Table 2. Processing conditions during the conversion of the dewatered yam mash to breakfast food.

S/No	Parameter	Value
1.	Temperatures	
	(i) Dewatered trifoliate yam mash:	
	after fermentation	32°C
	after sieving	29-30°C
	during garification	85-102°C
	(ii) Toasting surface of the pan:	
	onset of garification	
	Base	77-100°C
	Top	70°C
	during garification	
	Base	100-119°C
	Top	85°C
	(iii) Breakfast food:	
	immediately after garification	85°C
2.	after cooling	29-32°C
	Periodicity	
	(i) Toasting/garification time for 1.5kg batch	19-22 mins
	(ii) Intervals between stirring periods:	
	initial	14-18 secs
	later	40-45 secs
3.	(iii) Individual stirring period	25-35 secs
	Dimension	
	(i) Thickness of mash layer during garification:	
	unstirred	1-4.2 cm
4.	stirred	indeterminate (in a flux)
	pH	
	(i) Fermented dewatered yam mash	4.0

Table 2 gives the data for the major processing parameters encountered during the non-mechanized conversion of the dewatered fermented trifoliate yam mash to the dehydrated breakfast food. These data would be useful in designing a dehydrating cooking system for the yam mash. Stirring made it possible for the yam mash to have the varied processing temperature of 85-102°C during the toasting or dehydration process, on the garification pan. It was observed that all parts of a batch of the mash attained 100°C processing temperature before the garification process was over. With a pH of 4.0, the fermented trifoliate yam mash could be cooked and 'commercially sterilized' at temperature of 100°C (Fields, 1979; Okaka and Okaka, 2001). The observed long thermal processing time (for 1.5kg batch) of 19-22 minutes may be advantageous due to the principle of using longer processing time in eliminating endogenous spoilage microorganisms (Potter, 1987). The dehydrated product was allowed to cool to room temperature (29-32°C) before packaging in order to avoid internal 'sweating' (water vapour inside the package), and damage to the heat sensitive polyethylene packaging material.

The dry matter content of the fresh trifoliate yam tubers used for the breakfast food production was 28.37 ± 0.48%. This means a high tuber moisture content of about 70%. The weight of the trifoliate yam tubers used in the production ranged from 45g to 345g while the tuber density (g/cm³) ranged from 1.022 to 1.05g/cm³.

Table 3 shows that the percentage breakfast food yield, from the fresh trifoliate yam raw materials, was 14.36%. This was after a 27.44% peeling loss and 2.62% after-sieving chaff loss. Lye peeling, which could have given lower peel loss, is better avoided, because of the inherent danger of increasing the sodium content of the product. In addition to high-sodium food being a health risk to people prone to hypertension (Davidson *et al.*, 1975), the trifoliate yam breakfast food (in this study) was designed not to have any chemical food additives.

Plate 4.7 Photograph of a sample of the trifoliate yam breakfast food



Figure 3. The granular trifoliate yam breakfast food product in a polyethylene bag.

Table 3. Material yields and losses during the breakfast food production.

Material	% Yield (loss)*
Peel loss	(27.44 ± 0.30)
Dewatered pulp	30.43 ± 0.74
Chaff loss	(2.62 ± 0.17)
Breakfast food	14.36 ± 0.08

*Values in brackets are losses. Total watery material loss is not included.

The results of the experiment on aggregate size distribution of the trifoliate yam breakfast food are presented in Table 4. It was found that 76.4% of the breakfast food had aggregate sizes between 500µm and 2mm, while those between 250µm and 500µm were 17.08% of the total sample. The experiment also showed that though neither of the food particle was above 4mm nor below 63µm, 5.30% and 0.15% of the food particle were respectively above 2mm and below 150µm. This aggregate size distribution of the food particles indicates that the pre-gelatinized breakfast food material is granular and not floury; since an important characteristic of flour (from wheat and non-wheat starch staples) is that the particle size should be about or smaller than 130µm (UNECA, 1985). However, minor variations can exist due to the raw material and milling method employed (Potter, 1987; Akingbala and Rooney, 1990).

Table 4. Aggregate size distribution of the trifoliate yam breakfast food

Particle Size	Distribution (%)
0.00-0.063mm	0.00
0.063-0.150mm	0.15
0.150-0.250mm	0.87
0.250-0.500mm	17.08
0.500-1.000mm	30.90
1.000-2.000mm	45.50
2.000-3.350mm	5.04
3.350-4.000mm	0.26
≥4.000mm	0.00

Table 5 shows the physico-functional properties of the pre-gelatinized trifoliate yam breakfast food determined non-mechanically. The colour variations observed in the breakfast food particles ranged from cream to light yellowish brown or straw colour. This variation in the shades of colour amongst the food particles is probably due to differing levels of oxidative browning and caramelization in the particles before and during toasting.

The mean values for the water and oil absorption of the granular product are 4.00g/g and 1.71 g/g, respectively. The water and oil absorption capacities of food materials indicate how they would interact respectively in hydrophobic and hydrophilic environments of food preparations and/or systems (Abbey and Ibeh, 1988; Okezie and Bello, 1988). For example, the water absorption capacity will help to determine if the product could be incorporated into an aqueous food preparation. The mean emulsion capacity value is 13.89

g oil/g sample. This value is equivalent to that of winged bean flour (Okezie and Bello, 1988) and lower than that of raw cowpea flour (Abbey and Ibeh, 1988). High emulsion capacity is beneficial in food preparations that require emulsion and creaming properties (Kinsella, 1981).

Table 5. Physico-functional properties of the breakfast food.

Parameter	Value*/observation
Colour	Cream-light yellowish brown
Water absorption capacity (g/g)	4.00 ± 0.33
Oil absorption capacity (g/g)	1.71 ± 0.04
Emulsion capacity (g oil/g sample)	13.89 ± 0.03
Loose bulk density (g/cm ³)	0.40 ± 0.008
Packed bulk density (g/cm ³)	0.46 ± 0.004
Swelling index	1.74 ± 0.011

* Mean of six determinations ± standard deviation.

The bulk density of 0.40-0.46 g/cm³ for the dehydrated breakfast food indicates its level of lightness. The information on bulk density (amount of space occupied by a given food mass) is necessary for the packaging and warehousing the product.

The swelling index value of the food material in cold water (at 26°C) is 1.74 ± 0.011. Balagopalan *et al.* (1988) noted that pre-gelatinized starchy and particulate products have relatively high swelling index in cold and warm water, even before reaching the gelatinization temperature of the species' starch. This phenomenon is attributed to the reduction of the associative force in the native starch during the pre-gelatinization process. This dissociation of some amylose and amylopectin molecules from the native starch allows for increased swellability in water.

The results of the Brabender amylograph analyses of the paste characteristics of 15% suspension of the trifoliate yam, cassava and wheat samples are shown in Table 6. There were observed minor variations in the minimum and maximum gelatinization temperatures of the trifoliate yam starch and the trifoliate yam products. While the trifoliate yam starch had initial gelatinization temperature of 83.9°C and maximum gelatinization temperature of 87.6°C the corresponding values for the trifoliate yam breakfast food are 85.6°C and 91.8°C, respectively. The gelatinization temperature of trifoliate yam starch was given as 77-85.5°C by Kay (1987).

Non-starch materials in a starch suspension (in water) are known to affect its gelatinization temperature (Balagopalan *et al.*, 1988). Hydrophobic materials prevent easy gelatinization of starch while surfactants, like potassium palmitate and potassium stearate, penetrate starch helix (preventing entry of water molecules) and cause an increase in gelatinization temperature of the starch (Balagopalan *et al.*, 1988; Moorthy, 1994). In this study, it seems that partial pre-gelatinization increased the maximum gelatinization temperature of the starchy materials from trifoliate yam and cassava. The temperature range for the gelling of the wheat flour was observed to be higher than those of the materials from

trifoliate yam and cassava.

Table 6. Brabender amylograph readings for the experimental trifoliate yam, cassava and wheat products.

Sample	Minimum Gelatinization Temperature (°C)	Maximum Gelatinization Temperature (°C)	Maximum Viscosity (A.U.)
Trifoliate yam starch	83.9	87.6	1,150
Trifoliate yam flour (UF)*	80.5	91.2	1,030
Trifoliate yam flour (F)*	77.7	88.9	1,765
Breakfast food granules (TY)	+85.6	91.8	1,740
Breakfast food powder(TY)	+80.9	92.6	1,880
Cassava starch	76.9	78.2	1,405
Cassava gari	+77.2	88.9	1,970
Cassava gari powder	+39.4	83.6	2,120
Wheat flour	73.5	94.8	655

A.U. = Amylograph Unit

*UF = Unfermented

*F = Fermented; TY = Trifoliate yam product

+ = Presence of pre-gelatinization peaks

The maximum viscosity of the wheat flour (655 A.U.) was also lower than those of cassava and trifoliate yam; with cassava products having higher maximum viscosities than those of the corresponding trifoliate yam products. Pre-gelatinization, fermentation and powdering seemed to increase the maximum viscosity of the tuber products. Abiodun *et al.* (2013) also observed that pre-gelatinization and particle size reduction of trifoliate yam flour led to higher peak viscosity. It could be inferred that the trifoliate yam products, because of their relatively high viscosities, would not be suitable to replace wheat in baked products – as flours with high maximum gelatinization viscosity (above 1,000 A.U.) have dry crumb with the tendency to crack (Brabender, 1989). This is due to the fact that the starch binds a lot of water for the swelling and gelatinization. Brabender (1989) recommended 300-700 A.U. (maximum gelatinization viscosity) for bread-making flour or bakery flour. The trifoliate yam breakfast food may not also serve as a good alternative in the preparation of very viscous *eba* from cassava gari because of its relatively higher gelatinization temperature.

Table 7. Proximate composition of the trifoliate yam breakfast food.

Constituent	% composition*
Moisture	5.05 ± 0.02
Ash	1.20 ± 0.08
Fibre	3.63 ± 0.02
Protein	11.12 ± 0.15
Lipid (ether extract)	0.68 ± 0.01
Carbohydrates	78.32 ± 0.29

*Mean of six determinations ± standard deviation.

The results of the analyses for the proximate composition of the trifoliate yam breakfast food are shown in Table 7. Analysis of proximate composition of a food material

provides information on its basic chemical composition. Knowledge of the protein, fibre, lipid, ash and total carbohydrate content of the food is fundamental to the assessment of its nutritive quality (Bainbridge *et al.*, 1996; Okaka *et al.*, 2002). The low moisture content (5.05%) obtained for the product would probably contribute in discouraging the growth of spoilage and pathogenic microorganisms (Ezeama, 2007) in the water-proof polyethylene bags. Low moisture content is desirable for good shelf life, as water in addition to participating in chemical and biochemical reactions involving hydrolysis, also serve as a modifier of the catalytic activity of some other substances in foods (Okaka and Okaka, 2001).

The 1.20% ash content of the food material indicates its level of inorganic constituent. A relatively high ash value in a processed food may indicate contamination by inorganic materials (Owuamanam *et al.*, 2013). Owuamanam *et al.* (2013) gave the ash content of their produced trifoliate yam flour as 2.77%. The ash content of the drier cereal kernels are 1.3%, 1.6%, 1.8%, 0.5% and 1.6% for maize, millet, sorghum, polished rice and wheat respectively (UNECA, 1985). Low lipid content in stored cereal foods had long been recognized as a necessary factor in preventing the development of off-flavours from lipid oxidation and/or deterioration (Onimawo and Akubor, 2005). The 0.68% ether extract obtained for the trifoliate yam breakfast food is lower than the 7.5%, 4.3%, 3.3%, 2.3%, 1.8% fat content given by Davidson *et al.* (1975) for rolled oats, whole maize meal, millet (and sorghum), whole wheat meal and husked rice, respectively.

The fibre content (3.63%) of the breakfast food is relatively high when compared to 0.3-2.3% of the kernels of major cereals found in the tropical and semi-temperate countries (1.4%, 1.2%, 1.5%, 0.3%, 2.3% for maize, millet, sorghum, polished rice and wheat, respectively) (UNECA, 1985). There are claims that lack of fibre in the diet may be responsible for many of the diseases in the industrialized

western world, as fibre promotes the formation of soft bulky stool, intestinal peristalsis and adsorbs toxic substances in the large intestine and colon (Davidson *et al.*, 1975). Breakfast cereals produced in the industrialized Western countries are sometimes fortified with fibrous materials in order to get a higher fibre content (Proudlove, 1990). The 11.12% crude protein content of the experimental breakfast food is relatively comparable to the 12.2% for whole wheat meal, 9.5% for whole maize meal, 13.0% for rolled oats, 7.5% for husked rice and 10.1% for sorghum/millet (Davidson *et al.*, 1975). Oyenuga (1968) gave the crude protein content of dehydrated peeled trifoliate yam as 11.73%. Cystine is the limiting amino acid in yam protein, and trifoliate yam has the highest chemical score of cystine amongst the food yams (Degras, 1993).

The calculated caloric value of the trifoliate yam breakfast is 363.88 Calories/100g. Oyenuga (1968), and Agbor-Egbe and Treche (1984) respectively got 391.25Cal/100g and 381 Cal/100g for dehydrated trifoliate yam with the Atwater factors explained by Merrill and Watt (1973). This shows that the trifoliate yam breakfast food is also a good source of energy – if used in breakfast food preparation. Okaka *et al.* (2002) noted the slight decrease in the caloric value of some fermented vegetables due to utilization of the sugars (in the fresh vegetables) by the fermentation organisms. The 363.88 Calories/100g, got as the caloric value of the trifoliate yam breakfast food, is equivalent to 15.23 MJ/kg (15.23 megajoules per kg food material) or 1,523 kilojoules per 100g of food material. Davidson *et al.* (1975), in their diet sheets, gave the energy requirement for a normal diet suitable for a patient in bed as 8.4-10MJ for a day. This value range may require modification in relation to the age, size, sex and occupation of the patient (Davidson *et al.*, 1975). For example, they gave daily energy requirements of 4.2MJ for obese and diabetic patients and 12.6-14.7 MJ for convalescent patients, undernourished patients and those with wasting diseases. In the calculation of these energy requirements, it was assumed that the diet was well balanced (with adequate amounts of protein and the other nutrients). Milk, which is rich in protein, vitamins and minerals, is usually added to the energy rich breakfast cereals (such as oat meal and cornflakes) before consumption (Proudlove, 1990). Uncle Toby's white Oats and Jungle Oats brands of the oat breakfast foods, in the local Nigerian markets, have respective energy values of 1,480kJ/100g and 1,443kJ/100g inscribed on their individual packaging material, while Quaker White Oats' value is 1,540 KJ/100g. These values are similar to 1,523 kJ/100g for the experimental trifoliate yam breakfast food.

The mean pH (for five samples) of the 10% suspension of the trifoliate yam breakfast food was 4.20 ± 0.026 . This value is slightly less acidic than the pH of about 4.0 obtained for the fermented trifoliate yam mash in this study. Toasting or garification probably led to the loss of some volatile acids. The result for the total titratable acidity (TTA) (expressed as lactic acid) of the breakfast food was $0.34 \pm 0.01\%$ (for five determinations). All titratable organic acids in the plant

material and the organic acids produced during fermentation make up the total titratable acidity of the food product.

The result of the microbiological experiment with the diagnostic media for pathogens (Table 8) indicates the suitability of sealed polyethylene bags for up to one year storage of the dehydrated yam breakfast food. Okaka and Okechukwu (1993) and Ihekoronye (1999) had earlier observed the feasibility of storing dehydrated yam products with polyethylene bags.

Table 8. An assessment of post-processing microbial (pathogenic) contamination in the stored, packaged breakfast food.

Time (weeks)	MacConkey Agar (30°C/48 hrs)	PDA (30°C/120 hrs)
0	NG	NG
12	NG	NG
24	NG	NG
36	NG	NG
48	NG	NG
60	NG	NG

Key:

PDA = Potato Dextrose Agar

NG = No growth

The mean cooking (boiling) time of the trifoliate yam breakfast food obtained during the cooking trials was 1.83 ± 0.027 minutes. The breakfast food, with a mean cooking time of 1 minute 50 seconds (1.83 minutes) would unsurprisingly cook much faster than its trifoliate yam raw tuber. In the Republic of Cameroun, Bell (1984) observed a boiling time of 90 minutes for 1kg tuber of the local trifoliate yam variety. In Nigeria, Okoli (1993) got a mean boiling time (cooking time) of 30 minutes for 1cm³ cube of the edible (*ona*) variety of *Discorea dumetorum*. Okaka and Okaka (2001), and Oluwamukomi and Atofarati (2001) observed that cooking may help to make some food materials more palatable and digestible. This is due to the fact that cooking may alter colour, flavour and texture of the food material. Cooking may also eliminate the effect of some antinutritional factors (Okaka *et al.*, 2002).

The results of organoleptic analysis of the porridge prepared with the trifoliate yam product are shown in Table 9. The assessors generally liked (scores > 4.0) the product's sensory characteristics, even after one year of storage. However, the observed high standard deviations (Table 9) for these sensory characteristics indicate high variability in the scores of the assessors. Table 10 shows the comments of some of the assessors after testing the porridges (from the trifoliate yam breakfast food). The comments indicate individual preferences. Some observed negative comments on the meal from the stored product could be attributed to post-processing chemical changes. Nevertheless, it could be deduced that the experimental trifoliate yam product is generally suitable as a breakfast food after, being cooked and served hot with milk. However, individuals should be free to add sugar to their respective taste. Martin *et al.* (1984)

successfully used sugar to mask the bitter taste found in some trifoliate yam flours in Cameroon.

Table 9. Sensory evaluation scores of the trifoliate yam breakfast food porridge

Sample	Sensory characteristics				
	Colour	Taste	Flavour	Mouth-feel	General Acceptability
Fresh breakfast food	4.77 a $\pm$ 0.99	4.80 b $\pm$ 1.22	4.33c $\pm$ 1.25	4.33d $\pm$ 1.40	4.47e $\pm$ 1.12
Stored breakfast Food	4.60a $\pm$ 0.99	4.23b $\pm$ 1.09	4.27c $\pm$ 1.03	4.10d $\pm$ 1.27	4.40e $\pm$ 0.99

* mean values in a column with the same letter are not significantly different (P=0.05)

+ where

0 = dislike extremely, 1 = dislike highly

2 = dislike; 3 = neither like nor dislike

4 = like; 5 = like highly

6 = like extremely.

Table 10. Some assessors' comments on the prepared trifoliate yam porridge.

For	Against
1. Looks like oat meal	1. Need to improve on the mouthfeel.
2. Fresh product is okay	2. Stored product is not palatable.
3. I recommend the use of the product.	3. Poor colour, colour should be improved
4. Very palatable	4. Too sugary
5. Not too bad	5. Try to improve on the flavor
6. Better served hot	
7. The product should be named Yammie, Yammy or Yamma for easy marketability	

4. Conclusion

The results obtained in this research work showed the feasibility of producing an acceptable and storable product from trifoliate yams in Nigeria with adaptable and available technologies. The mechanical devices used for the processing operations (grating and dewatering machines) were locally fabricated and the complexities of their operations were within the scope of local cassava gari processors in Nigeria. Therefore, all the operations employed could be done in batches at micro or small to medium-scale food processing level without huge capital outlay- with relevant processing data for possible automated larger scale continuous production system. The acidic pH (below 4.5) and dryness (about 5% moisture content) of the well packaged product guarantees that the product is unlikely to be a source of dangerous pathogenic microorganisms. Table sugar can also be used to enhance the taste of the cooked breakfast meal from the trifoliate yam product.

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