Original Research Article

MORPHOLOGY, FUNCTIONAL AND PASTING PROPERTIES OF GINGER STARCHES PREPARED BY FOUR DIFFERENT DRYING METHODS

ABSTRACT

Aim: This study aims at providing information on the morphology, physico-chemical and pasting properties of the ginger starches prepared by air drying, oven drying, freeze drying and microwave drying methods with a view to improving their utilization.

Place and Duration of Study: Department of Pharmaceutics and Pharmaceutical Technology, Olabisi Onabanjo University, Nigeria and Department of Pharmaceutics, University of Ibadan, Nigeria between March 2013 and February 2014

Methodology: Starch was isolated from the rhizomes of *Zingiber officinale* and dried by oven, freeze drying, air drying and microwave drying methods. They were studied for their composition, morphological, functional and pasting properties

Result: The residual protein content of the four starches was slightly different averaging 5.06 %. The residual protein of air dried starch was the lowest and that freeze dried starch was the highest. There was no significant variation in the saponin and tannin contents of the dried samples. The amylose content of the ginger starches ranged between 20.7% and 22.1%.The rank order of the amylose content was microwave dried > freeze dried> air dried > oven dried. Drying methods had a significant effect (P<0.0001) on the solubility index and swelling capacity of the dried samples investigated. The rank order of the swelling capacity of the ginger starches was freeze dried < air dried < oven dried < microwave dried. A higher solubility index was observed among the oven-dried sample and the microwave sample compared to freeze dried and air dried samples. X-ray fluorimetric (XRF) analysis of the different starch powders showed the presence of iron, copper and zinc in trace amounts; and the absence of heavy metals like lead and mercury. All the four dried samples have fairly good flow. Significant differences were observed in individual pasting parameters of the ginger starches especially in peak viscosity, trough viscosity, final viscosity and setback viscosity. Peak viscosity was found to be lowest for freeze dried starch (300.42RVU) and highest for oven dried starch (324.25 RVU). The rank order of the final viscosity was oven dried > microwave dried > air dried > freeze dried.

Conclusion: This study revealed that the physicochemical as well as the pasting properties of the ginger starches prepared by the four drying methods make them to be considered as excellent resource with possible applications in many food and pharmaceutical processing. The results also showed that difference in drying methods during processing has an effect

on composition and pasting properties of ginger starch.

Keywords: Ginger starch; morphology; functional; pasting properties; drying methods

1. INTRODUCTION

Starch, the main reserve carbohydrate of several crops, is highly abundant in nature and can be easily extracted with high purity and low cost. Industries have been using starch for a long time as an ingredient in foods, especially for its functional properties. Depending on the source, starches have different applications in the food and pharmaceutical industries where they are used as fillers, glidants, thickners, binders, disintegrants as well gelling, bulking and water retention agents [1]. Starch which is a major dietary source of carbohydrate, is the most abundant storage of polysaccharide in plants, and occurs as granules in the chloroplast of green leave and the amyloplast of seeds, tubers and rhizomes. Starch consist of two molecules- the linear and helical amylose, and the highly branched amylopectin. They usually consist of 10-38 % amylose although the proportion often varies depending on the botanical source of the starch [2]. Tropical roots and tubers, grains, cereals and fruits are crops that have served as staple foods for millions of people throughout the world for many centuries and they generally have a high starch content which has made them potential sources of industrial starch.

Ginger is a perennial creeping plant, with thick tuberous rhizome, producing an erect stem 30 - 100 cm (1-3 ft) tall. The lance-shaped leaves are bright green, 15 - 20 cm (6-8 in) long, with a prominent longitudinal rib, enclosing conical clusters of small yellow-green flowers marked with purple speckles. It is propagated from rhizome cuttings, planted on rich, well drained loam. The underground rhizomes are the medicinal and culinary useful part of the plant. Ginger is widely used as a flavoring agent in beverages and many food preparations. Ginger helps relieve indigestion, gas pains, diarrhoea and stomach cramping. The primary known constituents of ginger root include starch, gingerols, zingibain, bisabolenel, oleoresins, essential oil (zingiberene, zingiberole, camphene, cineol, and borneol), mucilage, and protein.

Starch isolated from ginger rhizomes has been investigated for its use as pharmaceutical excipients [3-6] but it appears little or no work has been done to improve their functional properties and enhance their industrial uses in Pharmacy as thickener, binder, filling material and encapsulating agent. The increased requirements for starches in different applications, such as functional and healthier food, or applications in pharmaceuticals have thus forced a steady development of new starch types and the crucial need to understand the properties of the existing ones. This study was conducted to provide information on the morphology, physico-chemical and pasting properties of the ginger starches prepared by air drying, oven drying, freeze drying and microwave drying methods with a view to improving their utilization.

2. MATERIAL AND METHODOLOGY

2.1 MATERIALS

Ginger starch was extracted from ginger rhizome at the Department of Pharmaceutics and pharmaceutical technology laboratory of Olabisi Onabanjo University, Nigeria. Water was double distilled and all other chemicals were of analytical grade

2.2 METHODOLOGY

2.2.1 Extraction of Ginger starch from ginger rhizome

Rhizomes of ginger (*Zingiber officinale* Roscoe, Family Zingiberaceae) was washed with water, peeled and grated to produce ginger slurry. The grating was intermittently done to prevent the starch from heating up due to heat from grater. Enough quantity of distilled water was added to soak the material for 5 hours. The slurry was then thoroughly washed with water onto the muslin cloth into a collecting vessel to release the starch granules embedded in the parenchyma cells. The content of the collecting vessel was the allowed to settle for 2 hrs and the yellowish supernatant was decanted. Series of re-dispersion and decanting were done to remove impurities. The settled starch was scrapped off and divided into four equal parts, each of which was subjected into different drying methods which are; freeze drying, oven drying, microwave drying and open air drying.

2.2.2 Determination of Functional properties

2.2.2.1 Determination of bulk and tapped density

This was carried out for each sample using granules of mesh sizes of 500 – 1000 microns. A 50g sample was poured into a 50ml measuring cylinder and the bulk volumes were noted. The bulk density was calculated from the ratio of the mass to the bulk volume. The procedure was repeated and result obtained in triplicate. Tapped density determination was carried out by tapping the cylinder 100 times and the tapped volume obtained was used to calculate the tapped density.

2.2.2.2 Determination of particle density

The particle densities of the dried ginger starch powders were determined by the pycnometer method using liquid immersion technique with benzene as the displacement liquid. A 50 mL pycnometer bottle was weighed when empty (w). This was filled with benzene to the brim till it overflows. The excess was wiped off the bottle and its contents were weighed (W1). The difference between the two weights recorded was calculated (W2). A 2 g quantity of the ginger starch powder was weighed (W3) and quantitatively transferred into the pycnometer bottle. The excess solvent was wiped off and the bottle weighed again (W4). The particle density, ρ (g/cm3), was calculated from the following:

$$\rho = \frac{W2 . W3}{50\,(W1+W3-W4)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (1)$$

2.2.2.3 Determination of flow properties

A 30 g sample of the powders was poured into a plugged glass funnel with the tip, 10 cm above the flat surface of the bench. The granules were allowed to flow freely through the orifice of the funnel to form a heap whose height and diameter were determined. The angle of repose was calculated using the equation below:

$$\tan \theta = h/r \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (2)$$

Where h = height and r = radius of circular heap

The hausners ratio was calculated as the ratio of the tap density to the bulk density of the samples while the compressibility Index (C %) was calculated using bulk and tap densities data when fitted into the equation below:

Compressibility index = (tapped density-bulk density) / tapped density X 100 %............ (3)

2.2.2.4 Determination of Swelling capacity and solubility Index

The method described by Leach et al., 1959 [7] was used with slight modifications. Starch blends (1 g) were weighed and transferred into a clean dry test tube and weighed (W1). The mix was then dispersed in 50 mL of distilled water using a magnetic stirrer. The resulting slurry was heated at 80ºC for 30 minutes in a thermo stated water bath. The mixture was cooled to room temperature and centrifuged at 15 minutes. 5 mL of aliquot of the supernatant was dried to a constant weight at 120ºC. The residue obtained after drying represented the amount of starch solubilised in water. Solubility was calculated as per 100g of starch on dry basis. The residue obtained after centrifugation with the water it retained was transferred to the clean dried test earlier and re-weighed (W2).

Swelling of starch = (W2 – W1) / weight of powder x 100 …….. (4)

2.2.2.5 *Determination of moisture content*

A 5g powder was weighed in a tarred crucible and dried in hot air oven (Memmert Model 200) at 100±5ºC till a constant weight is obtained. The moisture contents were calculated by the formula given below. The mean of three determinations was taken as the final moisture content

$$MC = W_0 - W_1 / W_0 \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where MC is the moisture content and w_0, w_1 are initial and final weights of the starch respectively.

2.2.2.6 Determination of protein, tannin and saponin content

The protein and tannin content of the dried ginger starch samples were determined by established methods [8, 9]

2.2.2.7. Analysis of elemental constituents

Elemental analysis was carried out by the methods of Mineral Analysis using Atomic Absorption Spectrophotometer. Weight was recorded to the nearest 0.001g

2.2.2.8. Fourier Transform Infrared Spectroscopy (FT-IR)

The FTIR spectrum of the starches was recorded with a Perkin Elmer RXI spectrophotometer (Connecticut, USA). The dry powder was mixed with KBr and pressed into pellets. The spectrum was obtained by scanning between 4000 and 500/cm.

2.2.3 Determination of Pasting properties

Pasting characteristics were determined with a Rapid Visco Analyser (RVA Super 3, Newport Scientific Pty. Ltd, Australia). A 3 g sample was dissolved in 25 ml of water in a sample canister. The sample was thoroughly mixed and fitted into the RVA as recommended (Newport Scientific, 1998). The slurry was heated from 50 to 95°C with a holding time of 2 min followed by cooling to 50°C with another 2 min holding time. The 12 min profile was used and the rate of heating and cooling was at a constant rate of 11.25°C/min. Corresponding values for peak viscosity, trough, breakdown, final viscosity, setback, peak

time and pasting temperature from the pasting profile were read from a computer connected to the RVA.

3. RESULTS AND DISCUSSION

3.1 Morphology and Composition of ginger starches

The diversity of the shapes of the granules in ginger starches is shown in Figure 1-4. The shapes range from polyhedral/rounded/oval in air dried sample; irregular/orbicular/oval/reniform in freeze dried starch; oval/ellipsoidal/rounded in microwave dried starch and being oval/cordate/polyhedral in oven dried starch. Table 1 presents the composition and functional properties of the ginger starches obtained from the four drying method. The residual protein content of the four starches was slightly different averaging 5.06% (Table 1). The residual protein of air dried starch was the lowest while freeze dried starch had the highest. There was no significant variation in the saponin and tannin contents of the dried samples. The amylose content of the ginger starches ranged between 20.7% and 22.1%. The rank order of the amylose content of the starches was microwave dried > freeze dried > air dried > oven dried. The amylose portion of the starch affects its swelling and hot-paste viscosities. Shimelis and Rakshit (2005) stated that as the amylose content increases, the swelling tends to be restricted and the hot paste viscosity stabilizes. Based on the classification of starches by amylose content [11], all the four dried samples are intermediate (20-25% amylose).

3.2 Functional properties of ginger starches

Swelling capacity and solubility index provide evidence of the magnitude of interaction between starch chains within the amorphous and crystalline domains and also evidence of association bonding within the granules of starches [12]. Drying methods had a significant effect ($P<0.001$) on the solubility index and swelling capacity of the dried samples investigated. The difference in swelling capacity among starches from different drying methods indicates variation in the strength of associative bonding forces within the granules [7]. The rank order of the swelling capacity of the ginger starches was freeze dried < air dried < oven dried < microwave dried. The highest swelling capacity shown by microwave ginger starch might be indicative of weak bonding forces within its granules and the fact that it is less compact when compared to the other starch granules. The difference in amylose content and starch granular properties may also have affected the swelling capacity and solubility of the ginger starches. A low swelling capacity observed in the freeze dried sample may be due to stronger bonding force in its starch granules. A higher solubility index was observed among the oven-dried sample and the microwave sample compared to freeze dried and air dried samples. High solubility indices in starches has been attributed to the easy solubility of the linear fraction (amylose) which is linked loosely with the rest of the macro molecular structure, and released or leached out during the swelling process [18]. Microwave dried sample with the highest amylose content had the highest solubility index and swelling capacity. Starch granules become increasingly susceptible to shear disintegration as they swell and starches with lower amylose content swell more than those with higher amylose content.

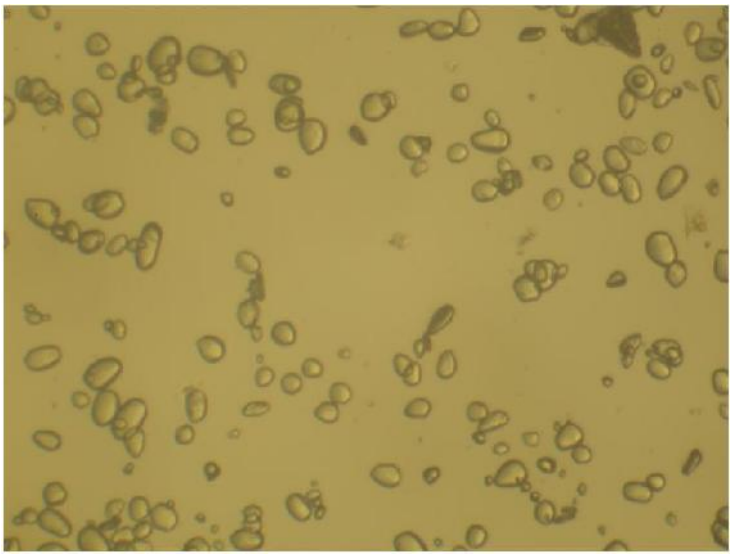

Figure 1: Photomicrography of freeze dried sample x10 magnification

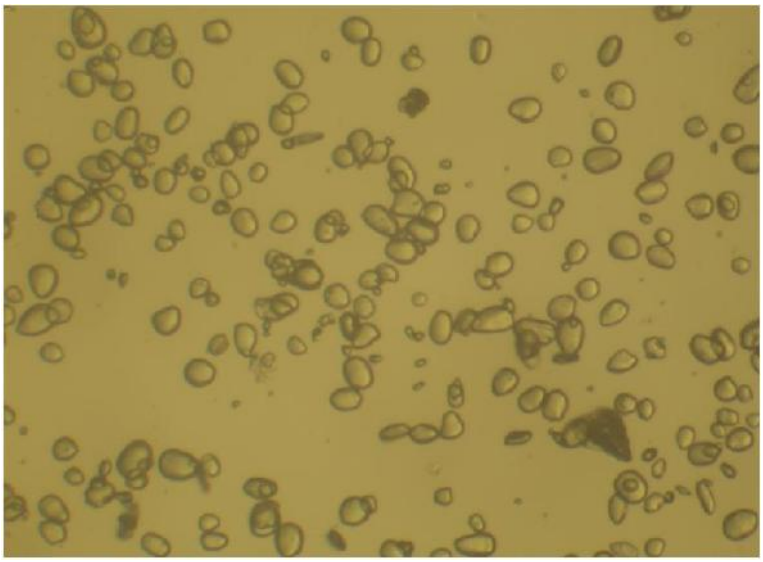

Figure 2: Photomicrography of oven dried sample x 10 magnifications

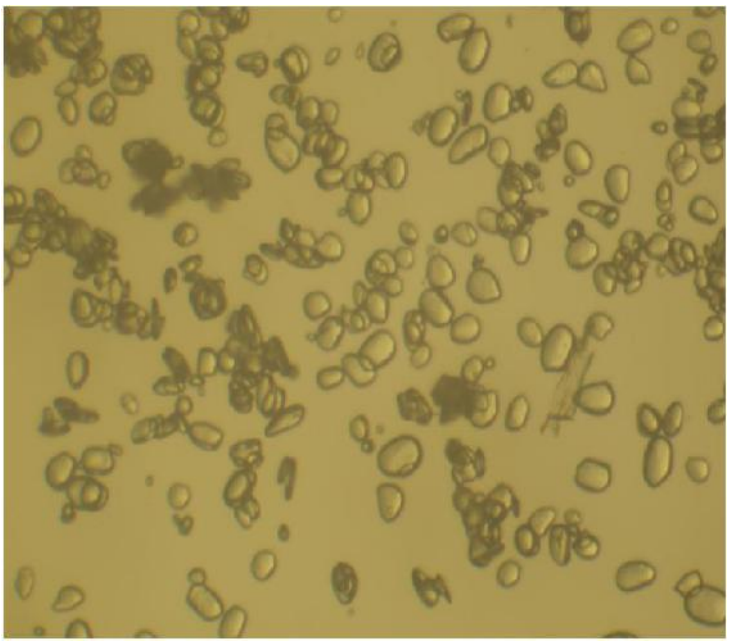

Figure 3: Photomicrography of microwave dried sample x 10magnifications

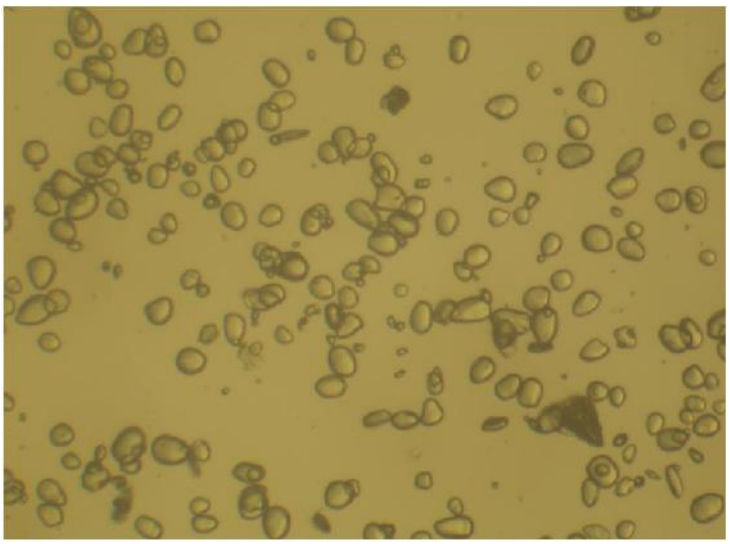

Figure 4: Photomicrography of air dried sample x10magnification

212 **Table 1: Functional properties of dried samples**

Drying Methods	Bulk Density (g/cm^3)	Tapped Density (g/cm^3)	Particle Density (g/cm^3)	Angle of Repose (^{0})	Carrs Index (%)	Swelling Capacity	Moisture Content (%)	Solubility (%)	Protein content	Tannin content (mg/100g)	Saponin content (mg/100g)	Amylose content (%)
Freeze dried	0.418	0.589	1.420	41.3	29.25	10.57	10.7	9.87	4.725	6.030	0.125	21.17
Oven dried	0.400	0.584	1.420	43.3	31.51	10.86	10.3	10.17	5.270	5.850	0.155	20.67
Microwave dried	0.383	0.563	1.420	42.7	31.97	10.93	10.8	10.28	4.885	5.870	0.135	22.06
Air dried	0.383	0.563	1.420	42.3	31.97	10.65	10.6	9.97	5.345	6.310	0.145	21.14

213

214

215

216

217

218

219

220

221

FTIR is a powerful technique to examine the formation of inter- and intra- molecular hydrogen bonds in starches. Fourier Transform Infrared Spectroscopy revealed the presence of O-H and C-O absorption bands in all the samples. Freeze dried sample had O-H and C-O absorption bands distinct at 3350.38 cm^{-1} and 1061.52 cm^{-1} respectively. Oven dried sample had 16 peaks while the air dried sample had 18 peaks. The British Pharmacopoeia, 2005 gives limit tests for a number of possible contaminants in pharmaceutical raw materials which may be introduced into the finished product during processing. Such tests include those for lead, arsenic, calcium, iron, potassium, aluminum, halogens and a host of others.

Table 2: Elemental constituent of dried samples

Elements	Freeze dried	Oven dried	Microwave dried	Air dried
Fe	0.195	0.215	0.235	0.185
P	121.055	112.260	109.46	120.145
Ca	5.230	5.345	5.175	6.350
Na	1.680	1.490	1.750	1.635
Mg	3.470	2.860	3.240	3.770
Zn	0.435	0.435	0.415	0.415
Mn	31.055	33.245	29.430	36.295
Al	0.000	0.000	0.000	0.000
K	21.470	20.45	23.59	24.230
Pb	0.000	0.000	0.000	0.000
Nickle	0.000	0.000	0.000	0.000
Selenium	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.000
Silicon	0.000	0.000	0.000	0.000
Cu	0.003	0.001	0.002	0.000

Although the pharmacopoeial requirements are not categorical on the exact tolerable level of any possible contaminant, it should not be presumed that unusual impurities are tolerated. X-ray fluorimetric (XRF) analysis of the different starch powders (Table 2) showed the presence of iron, copper and zinc in trace amounts. Heavy metals like lead and mercury were absent. The presence of heavy metals in formulated products is highly undesirable as they form stable covalent or co-ordinate complexes with body protein and can also act as catalyst (due to their variable valency state) to induce auto -oxidative reactions. The Pharmacopoeia has therefore placed strigent limits on the amount of lead and other heavy metals that may be present in pharmaceutical products [14]. Angle of repose, compressibility index and Hausner ratio determines the flow character or properties of powder particles. For an excellent flow, angle of repose must fall within the range of 25-30 degrees. All the four dried samples have fairly good flow which can be improved by the addition of a glidant if they are to be used in tablet formulation and production

Table 3: Pasting properties of Ginger starch powders

Drying Methods	Peak (RVU)	Trough/Hold (RVU)	Final Viscosity (RVU)	Breakdown (RVU)	Setback (RVU)	Peak Time (min.)	Pasting Temp (^{0}C)
Freeze dried	300.42	151.75	222.00	148.67	70.25	5.02	82.45
Oven dried	324.25	200.00	290.33	124.25	90.33	4.66	81.48
Microwave dried	306.42	163.42	236.00	143.00	72.58	4.58	82.66
Air dried	322.33	159.83	235.92	162.55	76.09	4.75	82.35

3.3 Pasting properties of ginger starches

Table 3 highlights the pasting properties of the starches. Pasting temperature of different ginger starches ranged from 81.5 to 82.7°C; the highest for microwave starch and the lowest for oven dried starch. Peak viscosity is the maximum viscosity attained by gelatinized starch during heating in water. It indicates the water binding capacity of the starch granule. Peak viscocity was found to be lowest for freeze dried starch and highest for oven dried starch. The rank order of the peak viscosity was oven dried > air dried > microwave > freeze dried. Trough viscosity was found to be the lowest for freeze dried starch (200.0 RVU) and the highest for oven dried starch (151.75RVU). Holding strength measures the ability of starch to remain undisrupted when paste is subjected to a long duration of high, constant temperature during the process of steaming. Oven dry method produced starch with the highest holding strength. Setback is a measure of re-crystallization of gelatinized starch during cooling. There are significant differences in the values of setback viscosity for the dried starches. The difference in setback among different starches may be due to the amount and the molecular weight of amylose leached from the granules of the gelatinized starch [15]. Oven dried sample had the highest final viscosity. Final viscosity indicates the ability of the starch to form a viscous paste. The rank order was oven dried > microwave dried > air dried > freeze dried sample. The increment in the final viscosity of paste made from oven-dried sample during cooling indicates formation of a firm gel after cooling, rather than a viscous paste as in the case of other-dried sample. The values of breakdown viscosity of the starch samples vary significantly. Breakdown viscosity is a measure of the vulnerability or susceptibility of the cooked starch to disintegration. The higher the breakdown in viscosity, the lower the ability of the starch sample to withstand heating and shear stress during cooking [16]. Therefore, oven dried starch (124.25 RVU) and microwave (143.0 RVU) starches might be able to withstand more heating and shear stress compared to starches from freeze dried starch (148.67 RVU) and air dried sample (162.55 RVU) because of their lower breakdown value. Starches with high paste stability or breakdown have very strong cross-linking within the granules [17]. It therefore means that there is stronger cross-linking within the granules of air-dried starch powder compared to the other dried samples.

4. CONCLUSION

The pasting and physicochemical properties obtained indicate that all the starches have useful technological properties for many applications. The data showed that the ginger

starch prepared by oven drying can be used as a functional ingredient in food systems. This study revealed that the physicochemical as well as the pasting properties of the ginger starches prepared by the four drying methods make them to be considered as excellent resource with possible applications in many food and pharmaceutical processing.

AUTHORS' CONTRIBUTIONS

Author BOA and BLG designed the study and wrote the protocol. Author BOA, BLG and FY managed the literature search and performed the statistical analysis. Author BLG, BOA and FY managed the analyses of the study while author BLG wrote the first draft of the manuscript. All the authors read and approved the final manuscript.

REFERENCES

1. Singh N, Singh J, Kaur L, Sodhi NS, Gill BS. Morphological, thermal and rheological properties of starch different botanical sources. Food Chem. 2003; 81: 219-231

2. Hoover R. Composition, molecular structure, and physicochemical properties of tuber and root starches, a review. Carbohydrate Polymers 2001; 45: 253-267.

3. Shok M, Kunle OO, Abdurahman EM. Ginger starch as tablet binder and disintegrant. Pharm. World J. 1992;9: 23-25

4. Ibezim EC, Ofoefule SI, Omeje EO, Onyishi VI, Odoh UE.The role of ginger starch as a binder in acetaminophen tablets. Sci. Res. Essay. 2008; 3: 946-950

5. Odeku OA, Odeniyi MA, Ogunlowo GO. Influence of ginger and banana starches on the mechanical and disintegration properties of chloroquine phosphate tablets. Asian Pac. J. Trop. Med. 2009;2:13-18

6. Prasanna A. Preparation and Evaluation of Combination Tablet Containing Paracetamol and Ginger Powder and Its Extract. Res Rev J Pharm Nanotech. 2013; 1(1): 7-11

7. Leach HW, Mc Cowen LD, Schoch TJ. Structure of the starch granules. In swelling and solubility patterns of various starches. Cereal Chemistry. 1959; 36: 534 – 544.

8. HACH. Procedures Manual. Systems for Food, Feed and Beverage Analysis. Hach Company World Headquarters , Colorado. 1990

9. Kardel M, Taube F, Schulz H, Schütze W, Gierus M. Different approaches to evaluate tannin content and structure of selected plant extracts – review and new aspects. J Appl Bot Food Qual. 2013; 86: 154 - 166 (2013), DOI:10.5073/JABFQ.2013.086.021

10. Shimelis AE, Rakshit SK. Proximate composition and physico-chemical properties of improved haricot bean (Phaseolus vulgaris L.) varieties grown in Ethiopia. J. Food Sci. Technol (LWT)2005; 38: 331-338.

11. Juliano BO. Structure and function of the rice grain and its fractions. Cereal Foods World. 1992; 37: 772-774.

12. Jimoh KO, Olurin TO, Aina JO. Effect of drying methods on the rheological characteristics and colour of yam flours. African Journal of Biotechnology. 2009; 8 (10): 2325-2328.

13. British Pharmacopoeia, Vol. II and IV. 2005. Her Majesty's Stationery Office, London. 2184-2186

14. United State Pharmacopoeia and National formulary 2006. Webcom Limited, Toronto, Asian Edition. 3259-61

15. Loh J. The effect of shears and strain on pasting behavior of food starches. Journal of Food Engineering. 1992; 16: 75-89.

16. Adebowale AA, Sanmi LO, Awonorin SO. Effect of texture modifiers on the physicochemical and sensory properties of dried fufu. Food Science Technology International. 2005; 5: 373-382.

17. Oduro I, Ellis WO, Argeetaoy SK, Ahenkora K, Otoo JA. Pasting characteristics of starch from new varieties of sweet potato. Tropical Science. 2000; 40 (1):25-28.

18. Soni RL, Sharma SS, Dun D, Gharia MM, Ahmedabad J. Physico-chemical properties of Quercus leucotrocophora (oak) Starch/Starke 1993; 45 (4): 127-130