American Journal of Food Science and Technology, 2017, Vol. 5, No. 1, 11-18
Available online at http://pubs.sciepub.com/ajfst/5/1/3

DOI:10.12691/ajfst-5-1-3

Proximate, Functional and Pasting Properties of Cassava Starch and Mushroom (*Pleurotus Pulmonarius*) Flour Blends

Ojo M.O.[1,*], Ariahu C.C.[2], Chinma E.C.[3]

[1]Department of Food Science and Technology, University of Mkar P.M.B. 017 Gboko, Nigeria
[2]Department of Food Science and Technology, University of Agriculture P.M.B. 2373 Makurdi, Nigeria
[3]Department of Food Science and Nutrition, Federal University of Technology P.M.B. 65 Minna, Nigeria
*Corresponding author: ojofoluso52@gmail.com

Abstract Our interest in this study is the production of cassava starch and mushroom (*Pleurotus pulmonaris*) composite blends for the purpose of edible film production. Therefore the determination of the proximate, functional and pasting properties is points of interest. Composite flour blends was prepared from Cassava starch (CS) and mushroom *Pleurotus pulmonarius* (MS) to obtain flour blends of cassava starch: mushroom (*P. pulmonarius*) flour; CS:MS 100:00, 90:10, 80:20, 70:30 and 60:40. The proximate, functional and pasting properties were determined using standard procedures and 100% cassava starch was used as control. The proximate analysis ranged from 8.79 to 9.35%, 0.55 to 26.23%, 0.34 to 2.01%, 0.32 to 8.24% and 0.10 to 17.86% for moisture, protein, fat and ash respectively while Carbohydrate ranged from 36.31 to 89.62%, amylose contents 18.47 to 25.35% and energy value ranged from 268.23 to 363.73Kcal. There were significant ($p \leq 0.05$) differences in the water absorption capacity, swelling power and solubility measured at various temperatures. The peak and trough viscosity ranged from 161.95 to 244.91RVU and 100.36 to 175.61 with the lowest value at CS:MS 60:40% and CS:MS100:00% as the highest. Final viscosity ranged from 227.32(CS:MS 60:40) to 315.10RVU (CS100%) while the pasting temperature and time ranged from 81.43 to 83.29 °C and 4.79 (CS:MS 80:20) to 5.75 (CS:MS 60:40%). These results suggest an improvement in the nutritional properties of the composite blends and strong dependence of the pasting and functional properties of the flours on the composition.

Keywords: *cassava starch, mushroom (P. pulmonarius), composite, functional, proximate, pasting*

Cite This Article: Ojo M.O., Ariahu C.C., and Chinma E.C., "Proximate, Functional and Pasting Properties of Cassava Starch and Mushroom (*Pleurotus Pulmonarius*) Flour Blends." *American Journal of Food Science and Technology*, vol. 5, no. 1 (2017): 11-18. doi: 10.12691/ajfst-5-1-3.

1. Introduction

Cassava (*Manihot escutenta Crantz)* is a major food crop in Nigeria, supplying about 70% of the daily calorie of over 50 million people in Nigeria [1]. It is the most important crop in terms of production and has also been estimated that cassava provides food for over 500 million people in the world [2] and [3]. The consumption of cassava has currently been on the increase and Nigeria has the largest cassava producer in the world since 1989 [3]. Starch is one of the major components of the dry matters in cassava, with a mean proximate composition of 58.90% [4]. Cassava starch has many remarkable characteristics including high paste viscosity and clarity as well as high freeze– thaw stability which are advantageous for industrial applications [5]. Starch contributes greatly to the textural properties of many foods and is widely used in food and industrial applications as a thickener, colloidal stabilizer, gelling agent, bulking agent, water retention agent and adhesive [6].

Oyster mushroom (*Pleurotus spp*) are the third mushroom of culinary value and are considered as a good source of protein and fibre which vary according to genetic structure of specie, physical and chemical differences in growing medium, composition of the substrate and harvest time. Edible mushroom contains all the essential amino acids as well as most commonly occurring non-essential amino acids needed for human nutrition especially lysine which is deficient in most cereal like wheat is the most abundant in mushrooms. Also, [7] reported that dried shiitake (*Lentinula edodes*) and oyster (*Pluerotus pulmonaris*) mushroom constituted a good source of microelements when used , and this can be used to solve micronutrients problems.

The functional properties are the fundamental physicochemical properties that reflects the complex interaction between the composition, structure molecular conformation and physicochemical properties of food components together with the nature of environment which are associated and measured [8,9]. Starch-based foods quality and nutritional properties are largely determined by the changes that starch undergoes during processing/cooking and subsequent storage. These changes, which determine the functional properties of starch involve water uptake, granule swelling, formation

of a viscoelastic paste during heating, followed by reassociation of dispersed starch chains on cooling and formation of a gel. Starch functionality is important for controlling moisture, viscosity, texture, consistency, mouth-feel and shelf-life of the finished products [10].

The study of the functional and chemical properties of cassava starch and mushroom flour blends is a subject of greater importance in order to evaluate advantages and disadvantages of its application. Therefore this study is aimed at producing cassava starch and mushroom flour and to study the chemical, functionality and pasting properties which would form a basis of processing protocol for the development into edible films.

2. Materials and Methods

2.1. Source of Raw Materials and Preliminary Handling

Cassava cultivar (TMS 30572) and Mushroom (*Pleurotus pulmonaris*) were obtained from Benue State Agricultural Development Authority and Federal Institute of Industrial Research Oshodi (FIIRO) Lagos Nigeria respectively.

2.2. Cassava Starch Extraction

Starch was extracted using the wet method as described by [11] with slight modification. Two kilogram of fresh tubers was peeled, washed, chopped into approximately 1cm cube and crushed to produce a pulp. The pulp was suspended in ten times its volume of deionised water and stirred for 5 minutes and filtered using double layered cheese cloth. The filtrate was allowed to stand for 2 hours and the water decanted. The mixture was stirred again and for 5minutes and filtration was repeated. The starch from the filtrate was allowed to settle and the sediment was removed and dried in the oven at 30^{o}C (PEK medical) for 72hours and milled with an attrition mill (R175A) into powder which was then sieved and packaged.

2.3. Preparation of Mushroom Flour

Mushroom (*P. pulmonaris*) mycelium were cleaned, sorted, sliced and dried in the oven at 50°C for 24hrs, milled with the use of attrition mill (Model R175A) into flours. The flours were sieved to obtain the mushroom flour (MS), and then properly package in transparent polyethylene bag and stored in desiccators.

2.4. Flour Blending

Cassava starch and mushroom were mixed in the different proportion 100:0, 90:10, 80:20, 70:30, 60:40 using a kenwood mixer (owBL335012) at speed 6 for 10mins to achieve a uniform blending

2.5. Chemical Analyses

2.5.1. Proximate Analyses

Moisture content, protein, Fat and Ash contents of cassava starch (CS), mushroom (MS) and their blends were determined using the AOAC [12] methods.

Carbohydrate content was calculated by difference [13]. The difference in value was taken as the percentage total carbohydrate content of the sample. Calculated thus:

$$\%\ \text{Carbohydrate content} = 100 - (\%\text{protein} + \%\text{moisture} + \%\text{fat} + \%\text{ash}).$$

The amylose content of cassava starch and their blends was determined using the method [13] involving the preparation of stock iodine solution and iodine reagent. A 0.1 g of starch was weighed into a 100 ml volumetric flask, then 1 ml of 99.7–100% (v/v) ethanol and 9 ml 1N sodium hydroxide were carefully added. The mouth of the flask was covered with paraffin and the contents were properly mixed. The samples were heated for 10 min in a boiling water bath to gelatinize the starch (the timing was started when boiling began). The samples were removed from the water bath and allowed to cool, then made up to the mark with distilled water and shaken thoroughly. Then, 5 ml was pipetted into another 100 ml volumetric flask and 1.0 ml of 1 N acetic acid and 2.0 ml of iodine solution were added. The flask was topped up to the mark with distilled water. Absorbance (A) was read using a spectrophotometer at 620 nm wavelength. The blank contained 1 ml of ethanol and 9 ml of sodium hydroxide, boiled and topped up to the mark with distilled water. Finally, 5 ml was pipetted into a 100 ml volumetric flask; 1 ml of 1 N acetic acid and 2 ml of iodine solution were added and then topped up to the mark. This was used to standardize the spectrophotometer at 620 nm. The amylose content was calculated as:

$$\text{Amylose content } (\%) = 3:06 \text{ x absorbance x } 20.$$

2.6. Energy Value

The energy value was calculated in KJ/100g, using the Atwater Factor Method, as described by [15]. It was calculated using the equation:

$$\text{E.V} = \begin{bmatrix} (9 \times \text{Crude Fat}\%) + (4 \times \text{Crude protein }\%) \\ + (4 \times \text{Carbohydrate }\%) \end{bmatrix}.$$

2.7. Assessment of Functional Properties

2.7.1. Water Absorption Capacity, Swelling Power and Solubility

The water absorption capacity and swelling pattern at 60, 70, 80 and 90°C were determined using the modified method of [16].

Forty millilitre of 1% cassava starch mushroom flour sample suspension (w/v) was prepared in a previously tarred 50ml centrifuge tube. The tube was placed in a water bath for 30min at constant temperature of 50, 60, 70, 80, 90°C. Each suspension was centrifuged at 4000g for 15min, then the supernatant was decanted and the swollen granule was weighed. 10ml sample was taken from the supernatant placed on a crucible and dried in an oven (PEC medical USA,) at 120°C for 4hours to constant weight. Water absorption capacity, solubility and swelling power was calculated using the following formulae

$$\text{Water absorption capacity} = \text{Mass of swollen granules} / \text{sample mass},$$

Percent solubility

= Weight after drying at 120°C x400 / sample mass,

$$\text{Swelling power} = \frac{\text{Weight of swollen granules x 100}}{\text{sample mass x } (100 - \text{solubility})}.$$

2.7.2. Gelation Capacity

Gelation capacity was determined using [17]. Suspension of 2-18g sample/ 100ml distilled water prepared and 10ml of each dispersion was transferred to a test tube. The tubes were then heated in a boiling water bath for 1hr followed by rapid cooling in a cold water bath . The tubes were further cooled at 4°C for 2hrs. The least gelation concentration (LGC) was determined as the concentration when the sample from the inverted test tube will not slip

2.8. Pasting Properties

Pasting characteristics were determined using a Rapid Visco Analyzer (Model RVA 3D+. Newport Scientific Australia). 2.5g of the sample of the cassava starch mushroom sample was weighed into a previously dried canister and 25 ml of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed and the canister was fitted into the Rapid Visco Analyser as recommended. Each suspension was kept at 50°C for 1min and then heated up to 95°C with a holding time of 2min followed by cooling to 50°C with 2min holding time. The rate of heating and cooling were at a constant rate of 11.85°C per min. Peak viscosity, trough, breakdown, final viscosity, set back, are read from the pasting profile with the aid of thermocline for windows software connected to a computer [18].

2.9. Statistical Analysis

One way analysis of variance (ANOVA) was conducted on each of the variables and the least significant difference (LSD) test at significant level P<0.05 was performed using SPSS 20 software for windows to compare the difference between treatment means. Results were expressed as the mean± standard deviation of triplicate determination.

3. Results and Discussions

3.1. Proximate Composition

The chemical composition of the cassava starch (CS), mushroom flour (MS) and their blends is shown in Table 1. The moisture, protein, fat, ash, fibre, carbohydrate and amylose contents ranged from 8.79 to 9.35%, 0.55 to 26.23 %, 0.34% to 2.01, 0.32 to 8.24 %, 0.10 to 17.86%, 36.31 to 89.62% and 18.47 to 25.35%. There was a significant difference (p<0.05) in all the samples.

The moisture content estimates directly the water content and indirectly the dry matter of the samples. According to [19,20], flours with moisture content less than 14% can resist microbial growth and hence storage stability. Therefore, the moisture content of the flour samples which falls between 0 - 10% is within the range acceptable for effective flour storage for further processing without the risk of microorganism contamination. The very low protein value of the cassava starch is expected as raw cassava pulp protein content is extremely low and ranges between 1.00-3.00g/100g [21,22]. Higher values of protein, fat, ash and fibre in the blends is due to the substitution with mushroom flour. However, the decrease in amylose content and this can be explained as the dilution factor of the mushroom as it does not contain amylose in its composition.

Table 1. Proximate Composition of Cassava and Mushroom (*Pleurotus pulmonaris*) Flour Blends

Nutrients (%)	Flour blends						
	CS(%)	100	90	80	70	60	0
	MS(%)	0	10	20	30	40	100
Moisture		9.07^{bc}±0.06	8.84^{d}±0.32	8.79^{d}±0.17	9.20^{ab}±0.03	8.94^{cd}±0.16	9.35^{a}±0.14
Protein		0.55^{f}±0.01	1.86^{e}±0.02	3.19^{d}±0.02	5.73^{c}±0.03	9.52^{b}±0.01	26.23^{a}±0.12
Fat		0.34^{f}±0.01	0.55^{e}±0.01	0.61^{d}±0.01	0.86^{c}±0.02	0.90b±0.01	2.01a±0.05
Ash		0.32^{f}±0.01	1.94^{e}±0.005	3.18^{d}±0.06	3.36^{c}±0.01	3.86^{b}±0.005	8.24^{a}±0.15
Fibre		0.10^{f}±0.02	1.08^{e}±0.01	1.91^{d}±0.02	3.05^{c}±0.03	5.55^{b}±0.02	17.86^{a}±0.03
Carbohydrate		89.62^{a}±0.06	85.74^{b}±0.03	82.33^{c}±0.15	77.80^{d}±0.07	71.23^{e}±0.19	36.31^{f}±0.23
Amylose (%Carbohydrate)		25.35^{a}±0.02	24.03^{b}±0.20	20.30^{c}±0.05	19.84^{d}±0.02	18.47^{e}±0.03	ND
Energy(kcal)		363.73±0.16	355.31±0.15	347.56±0.68	340.41±2.62	331.14±0.73	268.23±1.53

Values with the same superscript within a row are not significantly (p<0.05) different
CS= Cassava Starch,
MS= Mushroom (*P. Pulmonarius*) Flour.

There is scientific evidence proving that the intake of numerous essential and non-essential dietary components influences growth, development and performance as well as disease prevention [23]. The crude protein content of *P. pulmonaris* 26.23% is within the range of values of 23.63 to 46.63% reported by [24] for many edible mushrooms in Nigeria Therefore, *P.pulmonaris* mushroom can be ranked as protein-rich food and also good source of fibre. This could be advantageous in the formulation of composite blends.

The increase in protein, fat, ash, fibre contents in the blends as mushroom substitution increases can be attributed to mushroom inclusion in the blends. With the increase in fibre in the composition, the blends can be considered as fibre enriched. Fibre is one of the essential component that are often used to develop enriched foods as a consequence of their demonstrated functionality which contributes to the great offer of competitive functional foods in the market. Fibre is considered an efficient protective agent for a wide variety of illnesses, including cardiovascular disease, colon cancer and constipation [25,26]. In order to increase the consumption of fibre, the American Dietetic Association (ADA) recommended the inclusion of a variety of grains, mushrooms, vegetables, and fruits for an active and healthy life [27]. Also, the increase in the fibre content can be an added advantage in the production of cassava starch mushroom edible films as this can counterbalance the hydrophilic nature of plasticized starches which leads to improved handle-ability and general mechanical properties of the composite films as reported by [28,29] in the production of starch based film with the inclusion of fibre.

The energy values ranged 363.73 to 268.23kcal, it is well know that the energy content is affected by the proportion of fat, protein and carbohydrate therefore the mushroom sample had the lowest energy value. These blends therefore provides low energy [30], less than 400 kcal/l00g which gives about 17.30% of the daily energy intakes recommended for a 70 kg person. Therefore, these blends may be considered a new food product with low energy diet that not only increases the supply of some compounds, but with added healthy biological activities. Hence the use in edible film production will contribute to a wide varieties of the available ones.

3.2. Functional Properties

The water absorption capacity, swelling power and solubility is shown in Table 2, Table 3 and Table 4. The water absorption capacity, swelling power and solubility are all temperature dependent.

Water absorption capacity:

Water absorption capacity is the ability of product to incorporate water and water inhibition is an important functional traits in food such as sausages custards and dough. There was a significant difference ($p<0.05$) between the various blends. The water absorption capacity ranged 2.99 to 21.08g/g with the composite blend at cassava starch 100% cassava starch as the highest. According to [31], Flours with high water absorption capacity have more hydrophilic constituents such as polysaccharides. Also, [32] reported that starch that have high proportion of amorphous material would presumably have more water binding sites thus absorbing more water. Therefore the difference in water absorption capacity in the various blends may be due to different hydrophilic carbohydrate in the component as observed in their composition and the decrease in starch as mushroom is been substituted in the composite blends.

Table 2. Water Absorption Capacity (g/g) Of Cassava Starch And Mushroom (P. *Pulmonaris*) Flour Blends

Temperature	Flour Blends					
°C	CS(%)	100	90	80	70	60
	MS(%)	0	10	20	30	40
50		3.53^{a}±0.26	3.27^{b}±0.01	3.07^{c}±0.06	2.99^{d}±0.01	3.01^{d}±0.20
60		3.81^{a}±0.01	3.74^{b}±0.1	3.65^{c}±0.02	3.50^{e}±0.31	3.56^{d}±0.10
70		10.98^{a}±0.01	10.11^{b}±0.02	9.09^{c}±0.78	7.60^{d}±0.01	7.71^{d}±0.15
80		17.55^{a}±0.37	14.12^{b}±0.21	12.92^{c}±0.01	11.35^{e}±0.50	13.41^{c}±0.01
90		21.08^{a}±0.03	20.06^{b}±0.02	17.89^{d}±0.90	16.51^{e}±0.02	19.26^{c}±0.01

Values with the same superscript letters within a row are not significantly ($p<0.05$) different.
Where
CS= Cassava Starch
MS= Mushroom (P*leurotus pulmonaris*)flour.

Table 3. Solubility Pattern (%) of Cassava Starch and Mushroom (*P.pulmonarius*) Flour Blends

		Flour Blends				
Temperature	CS(%)	100	90	80	70	60
0°C	MS(%)	0	10	20	30	40
50		4.18^{a}±0.02	3.88^{b}±0.02	3.51^{c}±0.15	3.32^{d}±0.12	3.12^{e}±0.01
60		5.32^{a}±0.03	4.88^{b}±0.02	3.88^{c}±0.01	3.79^{d}±0.01	3.75^{e}±0.02
70		16.29^{a}±0.01	13.02^{b}±0.02	12.90^{b}±0.01	12.23^{c}±0.23	10.42^{d}±0.11
80		26.95^{a}±0.11	22.06^{b}±0.07	20.76^{c}±0.02	19.87^{d}±0.27	12.73^{e}±0.01
90		32.35^{a}±0.06	28.49^{b}±0.06	25.78c±0.02	23.02^{d}±0.01	18.91^{e}±0.76

Values with the same superscript letters within a row are not significantly ($p<0.05$) different
CS= Cassava Starch
MS= Mushroom Flour.

Table 4. Swelling Power of cassava starch mushroom (*P.pulmonarius*) Flour blends

Temperature 0°C	CS(%) MS(%)	Flour Blends 100 0	90 10	80 20	70 30	60 40
50		3.00^{a}±0.02	2.80^{b}±0.22	2.35^{d}±0.14	2.21^{e}±0.01	2.63^{c}±0.01
60		5.24^{a}±0.06	4.62^{b}±0.00	3.74^{d}±0.15	3.45^{e}±0.05	3.90^{c}±0.21
70		12.47^{a}±0.01	11.92^{b}±0.02	11.37^{c}±0.31	10.29^{e}±0.02	11.19^{d}±0.24
80		20.67^{a}±0.02	18.16^{b}±0.11	17.73^{c}±0.76	16.76^{d}±0.13	17.76^{c}±0.02
90		27.40^{a}±0.10	25.75^{b}±0.04	24.23^{c}±0.01	22.61^{d}±0.02	24.17^{c}±0.24

Values with the same superscript letters within a row are not significantly ($p<0.05$) different.
CS= Cassava Starch
MS= Mushroom Flour.

Solubility and swelling properties: The solubility and the swelling power provide the evidence of the interaction between starch chains between the amorphous and crystalline domain [38].

There is a significant difference ($p<0.05$) in the solubility of the various blends. The solubility ranged from 3.12 to 32.25g/g with 100% cassava starch having the highest value of 4.18 and 32.25g/g at 50°C and 90°C respectively. Solubility which is an indicator of degree of dispersion of granules after cooking [33] decreased with increase in substitution of mushroom in the blend, this could be as a result of mushroom increase in the composite flours as mushroom cell wall consist of non digestible carbohydrate such as constituted mainly by water-insoluble ones (IDF), with chitin and ß-glucans being the most representative ones, while the level of water-soluble ones (SDF) is usually less than 10% [34]. [35] stated that solubility could imply the amount of amylose leaching out when swelling, thus the higher the solubility the higher the amount of amylose leaching. The decrease in solubility of the composite blends may be as a result of low content of amylose in the composite blends.

The swelling power which is the measure of the ability of starch to imbibe water and swell or the extent of granule swelling in the various cassava starch mushroom blends, ranged from 2.21 to 27.40g/g, and with the highest value of 3.00 to 27.40 for 100% cassava starch at 50°C and 90°C respectively. When aqueous suspension of starch granules is heated in excess water, the structures are hydrated and the crystalline structure is disrupted due to breakage of the hydrogen bond. Water molecules becomes linked by the hydrogen bonding to the exposed hydroxyl group of amylose and amylopectin which causes an increase in granule swelling and amylose leaching [36]. [37] reported that highly associated starch granules display a greater resistance towards swelling, owing to an extensive and strongly bonding micelle structure which affects the film forming capability of starch.

The marked decrease in swelling properties as the mushroom substitution increases may be as a result of the behaviour of starch, the amylose content, structure of amylose, amylopectin, granule size and the presence of non carbohydrate substances especially lipids which acts as amylose swelling inhibitor [38,39]. It may also be due to starch and protein interaction due to attraction of their opposites charges to form inclusion complexes during gelatinization which restricts swelling [40]. The decrease in water holding capacity and swelling power of cassava starch and mushroom (*P. pulmonaris*) flour as substitution increases in the cassava starch mushroom composition at 70:30% and a sharp increase at 60:40% cassava mushroom blend, probably indicates the level at which the mushroom flours overpowers that of cassava starch flour sample. A similar trend was observed in swelling properties of Cassava starch durum wheat semolina and their blends; this was attributed to the weak internal organization [41]

Least Gelation Capacity

The least gelation capacity may be defined as the lowest concentration required for the formation a self-supporting gel. Samples with lower Least Gelation Capacity have greater gelling capacity [42]. The gelation properties of the various cassava mushroom blends will enhance their utilization in food system. The 100% cassava had the least gelation capacity (Table 5) hence, greater gelling capacity. Variations in gelling properties have been associated to the relative ratio of different constituents such as proteins, lipids and carbohydrates [43].

Pasting properties

Pasting properties are functional properties relating to the ability of an item to act in paste -like manner. [44]. According to [10], starch granules when heated become hydrated, swell, and are transformed into a paste. The granule structure collapses due to melting of crystallites, unwinding of double helices and breaking of hydrogen bonds. These changes are collectively referred to as starch gelatinization and are accompanied by the loss of characteristic birefringence of intact granules. On cooling, the disaggregated starch chains retrograde gradually into partially ordered structures that differ from those in native granules. There were significant differences ($p<0.05$) in the pasting profile. Table 6 shows the viscosity profile of the various blends.

Table 5. Least Gelation Capacity of Cassava Starch Mushroom Flour Blends

Samples	Concentration(g)		
CS:MS	8	10	12
100:00	-ve	+ve	+ve
90:00	-ve	±ve	+ve
80:20	-ve	±ve	+ve
70:30	-ve	+ve	+ve
60:40	-ve	+ve	+ve

-ve = No gel formed
+ve= gel formed
±= gel slightly formed
CS= Cassava Starch
MS=Mushroom Flour.

Table 6. Pasting Properties of Cassava Starch Mushroom (*P. pulmonaris*) Flour Blends

Rheological Parameter	Flour Blends				
CS(%) :	100	90	80	70	60
MS(%):	0	10	20	30	40
PV (RVU)	244.91^{a}±0.17	213.73^{b}±0.57	165.32^{c}±0.03	164.94^{c}±0.05	161.95^{d}±0.05
TV (RVU)	175.61^{a}±0.12	150.68^{b}±0.02	108.68^{c}±0.68	100.56^{d}±0.02	100.36^{d}±0.05
BD (RVU)	69.30^{a}±0.11	63.05^{c}±0.56	56.64^{e}±0.65	64.38^{b}±0.06	61.59^{d}±0.03
FV (RVU)	315.10^{a}±0.10	266.06^{b}±0.17	226.96^{d}±0.40	232.88^{c}±0.05	227.32^{d}±0.01
SV (RVU)	139.49^{a}±0.21	115.37^{e}±0.18	118.28^{d}±0.43	132.33^{b}±0.05	126.96^{c}±0.06
Peak Time (mins)	5.55^{b}±0.01	5.24^{c}±0.01	4.79^{d}±0.03	5.23^{c}±0.02	5.75^{a}±0.11
Pasting Temp (°C)	83.29^{a}±0.08	81.85^{c}±0.13	81.43^{d}±0.13	82.90^{b}±0.30	81.76^{c}±0.01

Values with the same superscript within a row are significantly different at $p<0.05$ CS= Cassava Starch,
MS= Mushroom Flour
PV= Peak viscosity
TV= Trough viscosity
BD=Breakdown viscosity
FV= Final viscosity.

The peak viscosity is the maximum viscosity attained by gelatinized starch during heating in water or soon after the heating portion of the various cassava starch mushroom (*P.pulmonarius*) blends ranged from 161.95 to 244.91RVU. 100% cassava starch had the highest while CS:MS at 60:40% had the lowest. The peak viscosity has been reported to be closely associated with the degree of starch damage. High starch damage results in high peak viscosity and starch binding capacity of the granules [40,46]. High peak viscosity is an indication of the suitability of the blends for products requiring high gel strength and elasticity.

Trough viscosity (TV) which is the minimum viscosity value measures the ability of paste to withstand breakdown during cooling ranged between 100.36 to 175.61RVU for CS:MS 100:00% and 60:40% respectively. The values of breakdown viscosity which is the measure of the susceptibility or vulnerability of the cooked starch sample to disintegration were significantly different ($p<0.05$) and ranged between 56.64 to 69.30 RVU at CS:MS 80:20 and 100%. The high values recorded is not surprising as high peak viscosities are associated with breakdown viscosity which in turn, are related to the degree of swelling of the starch granules during heating [46]. A low breakdown value however suggests the stability of starches under hot conditions. Amylose content is believed to have a marked influence on the breakdown viscosity (measure of susceptibility of cooked starch granule to disintegration) [47]. [48] reported that the higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking. Hence, the 100% cassava starch sample might not be able to withstand heating and shear stress compared to other mushroom substituted samples because of their lower breakdown values.

During cooling, reassociation between starch molecules especially amylose will result in the formation of a gel structure and therefore the viscosity will increase to a final viscosity [52]. The final viscosity is the most commonly used parameters to determine a particular starch-based sample quality. It gives an idea of the ability of a material to gel after cooking. The final viscosity of the 100:00 CS:MS starch flour recorded the highest value of 315.10 (RVU) and the lowest value of 226.96RVU for composite blend at CSMS 80:20%. The final viscosity is used to define the particular quality of starch and indicates the stability of cooked paste in actual use. It also indicates the stability to form various paste or gel after cooling. Less stability of paste is accompanied with high value of breakdown [49].

The setback value of the blends ranged between 115.37 to 139.49 RVU. Higher setback results in lower retrogradation during cooling of products [49]. When starch is heated in the presence of water and subsequently cooled, the disrupted amylose and amylopectin chains can gradually reassociate into a different ordered structure in a process termed retrogradation. Starch retrogradation is usually accompanied by a series of physical changes such as increased viscosity and turbidity of pastes, gel formation, exudation of water [50].

Pasting time is the measure of the cooking time [48]. The pasting time ranged from 4.79 to 5.75min and the pasting temperature is a measure of the minimum temperature required to cook a given food sample. Flour blends with higher pasting temperature may not be recommended for certain products due to high cost of energy [51]. The pasting temperature range of 81.43 to 83.29RVU was observed for the cassava starch mushroom (*P.pulmonarius*) blends. Pasting temperature has been related to water binding capacity [48], therefore the observed lower pasting temperature in the 90:10, 80:20, 70:30 and 60:40 cassava starch mushroom (*P. pulmonarius*) blends compared with the 100% cassava starch blends can be due to the low water absorption capacity of the blends.

4. Conclusions

Overall the functional, chemical and pasting properties had significance variance in the cassava mushroom blends.

The mushroom (*P.pulmonarius*) inclusion improved the protein, fibre and ash while there was a decrease in energy and the amylose content. In general, the water absorption capacity, solubility and swelling capacity decreased with the increase in mushroom substitution. High pasting values were also recorded for the cassava mushroom blend 100% compared to other blends. These information can be utilised in the preparation of textured products and advantageous in the improvement of water barrier properties in edible films production.

Acknowledgements

The author is grateful to the University of Mkar, Gboko for providing the facilities and an enabling environment to carry out this research work.

References

[1] Oluwole, O.B., Olatunji, O.O. and Odunfa, S.A. (2004). A process technology for conversion of dried cassava chips into gari. Journal of Food Science and Technol. 22: 65-77.

[2] Abu J.O., Badifu, G.I.O and Akpapunam, M.A. (2006). Effect of Crude palm-oil inclusion on some physico-chemical properties of gari, a fermented cassava food product. Journal of Food Science Technolology. 24: 73-79.

[3] Asante-Pok, A. (2013). Analysis of incentives and disincentives for cassava in Nigeria. Tecnhinical note series, MAFAP, FAO Rome. www.fao.org/mafap.

[4] IITA (1990), International Institute of Tropical Agriculture publication.

[5] Nwokocha, LM, Aviara, N.A., Senan, C. and Williams, P.A. (2009). A comparative study of some properties of cassava and cocoyam starches. *Carbohydrate Polymer* 76:362-367

[6] Goel, P.K., Singhal, R.S. and Kulkarni, P.R. (1999). Studies on interaction of corn starch with casein and casein hydrolysates. *Food Chemistry* 64:383-389.

[7] Regula, J and Silwulski, M. (2007). Dried shitake (*lentinula edodes*) and oyster (*Pleurotus ostreatus*) mushroom as a good source of nutrients. Acta Sciientiarum Polonorum Technologia Ailmentaria 6(4): 135-142.

[8] Siddiq, M. Nasir, M., Ravi, R., Dolan, K.D. and Butt, M.S. (2009). Effects of defatted, maize germ addition on the functional and textural properties of wheat flour. *International Journal of Food Properties.* 12: 860-870.

[9] Singh, N.L., Kaur, N.S., Sodhi, and Khon, K.S. (2005). Physico-chemical, cooking and textural properties of milled rice from different Indian rice cultivars. Food Chemistry.: 89:253-259.

[10] Wang, S.J. and Copeland, L. (2013). Molecular disassembly of starch granules during gelatinization and its effect on starch digestibility: A review. Food and Function 4 (11):1564-80.

[11] Benesi, I.R.M., Labuschagne, M.T., Dixon, A.G.O. and Mahungu, N.M. 2004. Stability of native starch quality parameters, starch extraction and root dry matter of cassava genotypes in different environments, *Journal of Science, Food and Agriculture*., 84: 1381-1388.

[12] AOAC, (2012). Official methods of analysis, Association of official analytical chemist 19th edition, Washington D.C., USA.

[13] Onwuka, G. I. (2005). Food Analysis and Instrumentation. Naphtali Print , Surulere, Lagos., Nigeria.P. 93-140.

[14] Williams, F.D., Kuzina, F.D and Hlynka, I. (1970). A rapid colorimetric procedure for estimating the amylose content of starches and flours. *Cereal Chemistry* 47:411-420.

[15] Osborne, D.R. and Voogt, F. (1978). The Analysis of Nutrients in Foods. London: Academic Press.

[16] Sathe, S.K. and Salunkhe, D.K. (1981). Functional properties of Great Northern bean (*Phaseolus vulgaris*). *Journal of Food Science* 46:71-75.

[17] Coffman, C.W. and Garcia VV (1977). Functional properties and amino acid content of protein isolate from mung bean flour. *Journal of Food Technology*12:473-484.

[18] Newport Scientific (1998). Applications manual for the rapid viscotmanalyzer using thermocline for windows. Newport scientific pty Ltd. Australia. P. 2-26.

[19] Hayma J. (2003). The storage of tropical agricultural products. Agromisa Foundation: Wageningen, Netherlands; P. 84.

[20] Arkroyed, W.R. and Doughty, J. (1994). Legumes in Human Nutrition. Food and Agricultural Nutrition Studies Publication. Lima Bean (*Phaseolus Lunatus*). 1:349.

[21] Buitrago, A.J.A. (1990). La yuca en la alimentación animal. Centro Internacional de Agricultural Tropical (CIAT), Cali, Colombia p. 446.

[22] Salcedo, A., Valle, A.D., Sanchez, B., Ocasio, V., Ortiz, A., Marquez, P., and Siritunga, D. (2010). Comparative evaluation of physiological post-harvest root deterioration of 25 cassava (*Manihot esculenta*) accessions: visual vs. hydroxycoumarins fluorescent accumulation analysis. *African Journal of Agricultural Research* 5: 3138-3144.

[23] Milner, J.A. (2002). Functional foods and health: A U.S. perspective. *British Journal of Nutrition* 88, Supplementary. 2, S151-S158.

[24] Adejumo, T.O. Coker, A. and Akinmoladun,V.O. (2015). Identification and evaluation of nutritional status of some edible and medicinal mushroom in Akoko area Ondo state, Nigeria. *International Journal of Cur Microbiology and Applied Science*. 4(4):1011-1028

[25] Marlett, J.A., McBurney, M.I. and Slavin, J.L. (2002). Position of the American Dietetic Association: health implications of dietary fibre. *Journal of America Dietician Association.* 102: 993-1000.

[26] Castro, I.S., Barroso, L.P. and Sinnecker, P. (2005). Functional foods for coronary heart disease risk reduction: A metaanalysis using a multivariate approach. *American Journal of Clinical Nutrition.* 82, 32-40.

[27] Johnson, R.K. and Kennedy E. (2000): The dietary guidelines for Americans; What are the changes and why were they made. *Journal of American Dietetic Association*, 100: 769-774.

[28] Muller, C., Laurindo, J. and Yamashita, F. (2009a). Effects of cellulose fibers on the mechanical properties and water vapour barrier of starch based films. *Food Hydrocolloid* 23 (5) 1328-1333

[29] Muller, C., Laurindo, J and Yamashita, F. (2009b). Effects of cellulose fibers on the crystallinity and mechanical properties of starch based films at different relative humidity values. *Carbohydrate Polymers* 77. (2) 293-299.

[30] Edmond A. D., Djary M. K. and Yolande D. D. (2016). Physicochemical and Functional Properties of Flour from the Wild Edible Mushroom *Termitomyces Heimii Natarajan* Harvested in Côte d'Ivoire. *Turkish Journal of Agriculture - Food Science and Technology*, 4(8): 651-655.

[31] Aremu, M.O. Basu, S.K., Gyar, S.D., Goyal, A., Bhowmik, P.K. and Datta, B.S. (2009). Proximate composition and functional properties of mushroom flours from G*anoderma spp, Omphalotus olearius* (DC) Sing .and *Hebeloma mesophaeum* (pers) (Quel). Used in Nasarawa state Nigeria. *Malaysian Journal of Nutrition* 15 (2)233-241.

[32] Lawal, O.S. (2004). Composition, physicochemical properties and retrogradation characteristics of native, oxidized, acid thinned new cocoyam (*Xanthosoma sagittifolium*) starch. *Food Chemistry*. 87, 205-218.

[33] Bhupender, S.K., Rajnesh, B. and Baljeet, S.Y. (2013). Physicochemical, functional, thermal and pasting properties of starches isolated from pearl millet cultivars. *International Food Research Journal* 20(4) 1555-1561

[34] Cheung, P.C.K. (2008). Nutritional value and health benefits of mushrooms, in: P.C.K. Cheung (Ed.), Mushrooms as Functional Foods, Wiley, Hoboken, P. 71-110.

[35] Srichuwong, S. Suharti, C., Misharti, Mishima, T. Isono, M. and Isamatu, M. (2005). Starches from different botanical sources. Contribution of starch structure to swelling and pasting properties. *Carbohydrate polymer* 62(1) 25-34.

[36] Bemiller, J. and Whistler, R. (2009). Starch: Chemistry and Technology 3rd ed. P. 310- 315. Academy press USA.

[37] Umar S, Farah N, Adil G, and Masoodi, F. A. (2016). Art and Science behind Modified Starch Edible Films and Coatings: A Review. *Comprehensive review in food science and food safety*. 15(3) 568-580.

[38] Tester, R. F. and Morrison, W. R. 1990. Swelling and gelatinization of Cereal starches II. Waxy rice starches. *Cereal Chemistry* 67(6): 551-557.

[39] Singh, N., Singh, J. Kaur, L., Sodiu, N.S. and Gill, B.S. (2003). Morphological thermal and rheological properties of starches from different botanical sources. *Food Chemistry.* 81: 219-231.

[40] Shimelis, A.E., Meaza, M. and Rakshit, S. (2006). Physico-chemical Properties, Pasting Behaviour and Functional Characteristics of Flours and Starches from Improved Bean (*Phaseolus Vulgaris L.*) varieties Grown in East Africa. *CIGRE Journal* 8: 1-18.

[41] Oladunmoye, O., Ogugua, C., Aworh, B.M, Ochuko, L. E. and Elemo, G. N (2014). Chemical and functional properties of cassava starch, durum wheat semolina flour, and their blends. *Food Science and Nutrition* 2(2): 132-138.

[42] Boye, J., Zare, F. and Pletch A. (2010). Pulse protein processing and characterization, functional properties and application in foods and feed. *Food Research International* 43: 414- 431

[43] Chan, C.F. and Cheung, P.K. (1998): Functional Properties of flours from three Chinese indigenous seeds. *Food Chemistry*., 61: 429-433.

[44] Otegbayo, B. O., Aina, J.O. and Asiedu, R. (2006): Effect of Storage on the Pasting Characteristics of Yam Starches. Proceedings of 30th annual Conference of Nigerian Institute of Food Science and Technology, P. 187-188.

[45] Sanni, L. O.; Ikuomola, D. P. and Sanni, S. A. (2001). Effect of length of fermentation and varieties on the qualities of sweet potato gari processing. 8th Triennial symposium of the International Society for Tropical Root Crops IITA Ibadan, Nigeria, P. 208-211.

[46] Ribotta, P.D., Colombo, A., León, A.E. and Añón, M.C. (2007). Effects of soy protein on physical and rheological properties of wheat starch. *Starch/ Stärke*, 59:614-623.

[47] Venema, K., Minekus, M., and Havennar, R. (2004). Advance in vitro models of the gastrointestinal tract – Novel tools to study functionality of dietary fibres. In J.W. van der Kamp, N.-G. Asp, J. Miller Jones, & G. Schaafsma (Eds.), Dietary fibre: bio-active carbohydrates for food and feed (P. 108). The Netherlands: Wageningen Academic Press.

[48] Adebowale, A.A., Sanni, L.O. and Awonorin, S.O. (2005). Effect of texture modifiers on the physicochemical and sensory properties of dried fufu. *Food Science and Technology International.* 1(5): 373-382.

[49] Ikegwu, O.J., Okechukwu, P.E., and Ekumankana, E.O. (2010). Physico-chemical and pasting characteristics of flour and starches from *Achi Brachystegia* seed. *Journal of Food Technology* 8(2). 58-66.

[50] Hoover R, Hughes T, Chung HJ and Liu, Q. (2010). Composition molecular structure, properties and modification of pulse starches: A review. *Food Research International* 43:399-413.

[51] Abioye, V.F, Ade-Omowaye, B.I.O, Babarinde, G.O and Adesigbin, M.K (2011). Chemical, physico-chemcial and sensory properties of soy-plantain flour. *African Journal of Food Science* 5(4), 176-180.

[52] Ragaae, S., El Sayed, M. and Abdel –Aal. (2006). Pasting properties of starch and protein in selected cereals and quality of their food products. *Food Chemistry* 95: 9-18.