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Full Length Research Paper

Changes in nutrient and antinutrient composition of popcorn and groundnut composite flour subjected to solid substrate fermentation

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Popcorn and groundnut composite flours were fermented by solid substrate fermentation method for 96 h. The following isolates were isolated from the fermentation; *Staphylococcus sp.*, *Lactobacillus fermentum*, *Bacillus sp.*, *Aspergillus* sp., *Saccharomyces cerevisiae, Rhizopus nigricans* and *Penicillium sp.* There was decrease in pH with increase in titratable acidity (TTA) in all the samples. The result of the proximate analysis revealed that the protein content of the fermented samples was between 7.92 to 18.13% compared to the unfermented samples (popcorn flour 7.49% and groundnut flour 24.69%). There was increase in fat and crude fibre contents and decrease in carbohydrate and ash contents of the fermented samples. The mineral analysis result showed that the level of potassium in all the samples increased markedly while there were marked reduction in the levels of magnesium and calcium in all the samples. The effect of fermentation on the antinutritional content showed that there was a decrease in phytic acid and tannin contents and an increase in oxalates content in some fermented samples.

Key words: Popcorn flour, groundnut flour, solid-state fermentation, nutrient, antinutrient.

INTRODUCTION

Solid-state fermentation (SSF) has emerged as a potential technology for the production of microbial products such as feed, fuel, food, industrial chemicals and pharmaceutical products. It is the fermentation involving solids in absence (or near absence) of free water; however, substrate must possess enough moisture to support growth and metabolism of microorganism (Pandey et al., 2001).

The growth of microorganisms on moist solid in nature is stimulated by SSF. Solid substrates generally provide a good dwelling environment to the microbial flora comprising bacteria, yeast and fungi. Among these, filamentous fungi are the best studied for SSF due to their hyphal growth, which have the capability to not only grow on the surface of the substrate particles but also penetrate through them. Several agro crops such as cassava, barley, etc. and agro-industrial residues such as wheat bran, rice bran, sugarcane bagasse, cassava bagasse, various oil cakes (for example, coconut oil cake, palm kernel cake, soybean cake, ground nut oil cake, etc), fruit pulps (for example, apple pomace), corn cobs, saw dust, seeds (for example, tamarind, jack fruit), coffee husk and coffee pulp, tea waste, spent brewing grains, etc are the most often and commonly used substrates for SSF processes. During the growth on such substrates hydrolytic exo-enzymes are synthesized by the microorganisms and excreted outside the cells, which create and help in accessing simple products (carbon source and nutrients) by the cells. This in turn promotes biosynthesis and microbial activities.

A glance at the history of fermentation technology indicates that the SSF processes were nearly completely ignored in western countries after 1940 due to adaptation of submerged fermentation (SmF) technology. However, perhaps there was no logical reasoning for this at that time. Since the development of penicillin took place in SmF and due to enormous importance of penicillin during the world war, SmF became a role model technology for production of any compound by fermentation. Subsequently, researchers of that time put their entire attention

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on SmF and probably unknowingly SSF was neglected. Still in the isolated pockets research continued on SSF systems and during 1950 to 1960, steroid transformation was reported using fungal cultures. The trend continued, although slowly and SSF attained another milestone during 1960–1970 when reports appeared on mycotoxins production by SSF. Production of protein enriched cattle feed was the next major activity reported, which involved utilization of agro-industrial residues, thus offering a unique process development for value-addition of these otherwise low cost residues (and to some extent environment pollutants). In fact, this was one of the areas, which generated interest of researchers globally on SSF. Since then, there has been continuous increase in the extension of SSF arena, which picked up strongly during the last one decade (Pandey, 2003).

SSF has been considered superior in several aspects to submerged fermentation (SmF) due to various advantages it renders. It is cost effective due to the use of simple growth and production media comprising agro-industrial residues, uses little amount of water, which consequently releases negligible or considerably less quantity of effluent, thus reducing pollution concerns. SSF processes are simple, use low volume equipment (lower cost), and are yet effective by providing high product titres (concentrated products). Further, aeration process (availability of atmospheric oxygen to the substrate) is easier since oxygen limitation does not occur as there is an increased diffusion rate of oxygen into moistened solid substrate, supporting the growth of aerial mycelium. These could be effectively used at smaller levels also, which makes them suitable for rural areas also (Pandey et al., 2001).

Zea mays averta is a type of corn which explodes from the kernel and puffs up when heated. Corn popping was originally discovered by Native Americans, but became popular as a snack food during the United States' Great Depression, especially in movie theatres. The corn is able to pop because its kernels have a hard, moisture sealed hull and a dense starchy filling. These allow pressure to build up inside the kernel until explosive 'pop' results. Each kernel of popcorn contains a certain amount of moisture and oil. The outer hull is strong and the starch inside consists almost entirely of a hard, dense type (Paliwal, 2000b).

The peanut *Arachis hypogaea* is a species in the legume 'bean' family. The cultivated peanut was likely first domesticated in the valleys of the Paraguay and Parana rivers in the Chaco region of Paraguay and Bolivia. It is an annual herbaceous plant growing 30-50 cm tall. The leaves are opposite and pinnate; each leaflet 1-7 cm long and 1-3 cm broad. The flowers are a typical pea flower in shape, 2-4 cm across, yellow with reddish veining. After pollination, the fruit develops into a legume 3-7 cm long, containing 1-4 seeds which forces its way underground to mature. Peanuts are known by many local names including earthnuts, groundnuts, gobberpeas, monkey nuts, pygmy nuts and pignuts (Pattee and Young, 1982).

The nourishment of snacks by fermentation is especially important due to the fact that many people now work outside their homes and are becoming more dependent on snacks for the supply of part of their daily nutritional requirements. Unfermented foods, snacks inclusive, contain complex compounds that need to be metabolized by enzymes in the stomach before absorption by the body. Fermentation, which are done by microbial enzymes, break down these complex food compounds into simple, easily assimilated compounds. With growing concerns for diet and general health, it is not unnecessary to know the nutritional or otherwise status of this snack. The objective of the research was to investigate the influence of fermentation on the nutritional composition of popcorn and peanut composite flour.

MATERIALS AND METHODS

Pop corn grains (*Zea mays averta*) were purchased from MDS area in Osogbo while the peanut (*Arachis hypogeae*) seeds were bought at Oja-oba market in Akure. Both the seeds and grains were thoroughly cleaned and screened to remove broken and cracked grains or seeds, dust, stones and other foreign materials. They were ground into flour with a hammer mill. The popcorn flour and groundnut flour were weighted and mixed in different proportion as follows:

(A1) PNF 7.5 g + PCF 22.5 g
(A2) PNF 15 g + PCF 15 g
(A3) PNF 22.5 g + PCF 7.5 g

Each sample was prepared in triplicate giving a total of nine samples: A1, A2, A3, O1, O2, O3, U1, U2 and U3.

Fermentation of samples

Samples A1, A2 and A3 were sterilized in an autoclave at 121℃ for 15, O1, O2 and O3 were oven-dried at 50℃ for 24 h while U1, U2 and U3 were untreated. A 40 ml of sterile water was added to each and allowed to ferment for 72 h at room temperature.

Microbial analysis

Daily changes in the microbial population (cfu/ml) of the total viable bacteria, lactic acid bacteria (LAB) and fungi were determined using standard plate count agar (Merck), de Man, Rogosa and Sharpe(MRS) agar (Merck) and malt extract agar (MEA, Merck), respectively. Samples were enumerated by using appropriate sterile dilution and spread plate methods. The fungal plates were incubated at 25℃ for 2 to 5 days while the bacterial cultures were incubated at temperatures ranging between 30 and 35℃ for 1 to 2 days. MRS agar was incubated at 25℃ for 2-5 days. MRS agar was incubated under anaerobic conditions simulated using a H_2/CO_2 generating kit (Oxoid) according to the manufacturer's instructions. Classification of isolates was based on the established methods using important biochemical and morphological observations and tests

Physiochemical changes

The pH of the sample was measured each day with a Cambridge

Table 1. Isolated microorganisms.

Method	0 h	24 h	48 h	72 h	96 h
Oven dried	*Saccharomyces cerevisiae, Penicillium, Rhizopus nigricans, Bacillus* sp.	*Saccharomyces cerevisiae, Penicillium, Rhizopus nigricans, Bacillus* sp., *Lactobacillus fermentum*	*Saccharomyces cerevisiae, Rhizopus nigricans, Bacillus* sp., *Lactobacillus fermentum*	*Saccharomyces cerevisiae, Rhizopus nigricans, Lactobacillus fermentum*	*Saccharomyces cerevisiae, Rhizopus nigricans , Lactobacillus fermentum*
Autoclaved	No growth	*Saccharomyces cerevisiae, Rhizopus nigricans , Penicillium* sp.,	*Saccharomyces cerevisiae, Rhizopus nigricans*	*Saccharomyces cerevisiae, Rhizopus nigricans*	*Saccharomyces cerevisiae, Rhizopus nigricans*
Untreated	*Bacillus* sp., *Penicilium* sp, *Staphylococcus* sp, *Aspergillus* sp., *Saccharomyces cerevisiae, Rhizopus nigricans Lactobacillus fermentum*	*Bacillus* sp.., *Penicilium* sp., *Staphylococcus* sp., *Aspergillus* sp.,, *Saccharomyces cerevisiae, Rhizopus nigricans Lactobacillus fermentum*	*Penicilium sp, Aspergillus* sp., *Saccharomyces cerevisiae, Rhizopus nigricans, Lactobacillus fermentum*	*Saccharomyces cerevisiae, Rhizopus nigricans, Aspergillus* sp., *Lactobacillus fermentum*	*Saccharomyces cerevisiae, Rhizopus nigricans Lactobacillus fermentum*

direct reading pH meter. Total titratable acidity (TTA) was determined on 5 ml aliquot of the sample against 0.01 N NaoH using phenol red as indicator according to AOAC (1995).

Chemical analysis

Proximate analysis of the sample was performed according to AOAC (1995) procedures for ash, crude fibre, fat, moisture and protein, using a nitrogen to protein conversion factor of 6.25. Carbohydrate was determined by difference. Phytate and tannin were determined using AOAC (1995) methods while oxalate content was by the titrimetric method (AOAC, 1995).

Mineral analysis

The nutritionally essential elements Na, Ca, Mg and K were determined using atomic absorption spectrophotometer ASS, while P was determined using UV-Visible spectrophotometer after making ammonium vanadate molybdate complex at 436 nm using established procedures of Perkin-Elmer (1996).

RESULTS AND DISCUSSION

In this study, three bacteria, one yeast and three mould were isolated. They are *Bacillus* sp., *Staphylococcus* sp., *Lactobacillus fermentum, Saccharomyces cerevisiae, Rhizopus nigricans, Penicilium* sp and *Aspergillus* sp. The organisms isolated from the samples are shown in Table 1. They were predominantly fungi especially the filamentous ones. This agrees with the work of Manpreet et al. (2005) that filamentous fungi are the major group of microorganisms which predominate in the SSF process. Filamentous fungi that are usually found associated with SSF process include many species of *Aspergillus, Rhizopus, Alternaria, Fusarium, Monilia, Mucor, Trichoderma* and some species of *Penicillium*. The microbes associated with fermentation of the composite flour were similar with few differences from those in untreated samples. At 0 h, the oven dried samples after incubation on nutrient and Potato dextrose agar plates, showed the growth of *S. cerevisiae, Penicillium, R. nigricans* and *Bacillus* sp. Due to the low water activity, the system created an unfavourable condition for bacterial growth, so bacterial colonization was minimal. Bacteria usually require at least 0.91 water activity while fungi require lesser water activity, 0.7. However, *Bacillus* sp, survived for 48 h before the rise of lactobacillus. The survival of Bacillus probably was due to their ability to form spores and withstand unfavourable conditions. The eventual disappearance of *Bacillus* may not be unconnected with the increase in the acidity of the medium as a result of the fermentative activity of the lactobacillus. Penicillium may also have disappeared for the same reason. After 96 h, *S. cerevisiae*, *L. fermentum* and *R. nigricans* were the organisms isolated from the system. There

Table 2. pH and titratable acidity.

Treatment	Composite	pH					Titratable Acidity (g/100)				
		0 h	24 h	48 h	72 h	96 h	0 h	24 h	48 h	72 h	96 h
Oven dried fermented	PNF 7.5g +PCF22.5 g	6.4	6.0	5.2	4.3	3.7	1.1	1.3	5.2	6.0	6.5
	PNF 15 g +PCF 15 g	6.5	6.2	5.5	4.6	4.1	1.3	2.4	4.3	5.5	6.0
	PNF 22.5 g +PCF 7.5g	6.2	5.8	5.1	4.2	3.8	1.1	1.8	4.2	5.8	7.2
Autoclaved fermented	PNF 7.5g +PCF22.5 g	6.4	6.1	5.0	4.5	4.0	2.1	2.5	2.8	4.6	5.0
	PNF 15 g +PCF 15 g	6.5	5.7	4.9	4.1	4.3	1.3	2.5	2.8	4.6	5.0
	PNF 22.5 g +PCF 7.5 g	6.2	5.0	4.4	3.6	3.9	1.8	3.2	4.3	5.1	5.8
Untreated	PNF 7.5 g +PCF22.5 g	6.4	6.0	5.2	4.3	3.7	2.0	4.1	5.1	6.0	8.2
	PNF 15 g +PCF 15 g	6.5	5.8	4.8	4.2	4.1	1.3	1.5	4.3	5.2	7.0
	PNF 22.5 g +PCF 7.5 g	6.2	5.5	4.6	3.9	3.5	1.6	3.7	5.3	6.2	7.8

was no growth at 0 h in the autoclaved samples. Killing of the most resistant spores due to exposure to moist heat at 121℃ for 10 to 30 min must have been responsibl e for no growth and few isolates present in the autoclaved samples (Frazier and Westhoff, 1988).

At 24 h, *S. cerevisiae*, *Penicillium* sp. and *R. nigricans* were found to colonizethe samples with *Penicillium* sp. disappearing at 48 h. *S. cerevisiae* and *R. nigricans* dominated the rest of the fermentation period. The isolation from the untreated samples revealed the presence of *Staphylococcus* sp. and *Aspergillus* sp. in addition to the isolates isolated from other samples. The presence of *Staphylococcus* sp. could have been as a result of contamination during handling and processing. *Aspergillus* sp. are known to be associated with grains where they cause toxification by the release of Aflatoxin. These microbes were absent in the other two samples probably due to the heat treatment the samples underwent.

Table 2 shows the pH and titratable acidity (TTA) values of the samples before, during and after fermentation. The pH of all the samples reduced as fermentation progressed with a corresponding increase in the titratable acidity values. This is in accordance with the findings of Mbata et al. (2009) who reported that during the fermentation of maize fortified with Bambara nut, the pH drops while the titratable acidity increases as the fermentation progresses. The untreated fermented sample with 22.5 g of peanut flour gave the lowest pH value of 3.5 with a corresponding titratable value of 7.8 g/100 lactic acid. The changes in pH and TTA could be attributed to the production of organic acids from available nutrients by fermenting microorganisms (Ojokoh, 2005).

The carbohydrate (given as Nitrogen free extract) levels of all the fermented samples were lower than those in the original raw sample (Table 3). The mean carbohydrate level for the oven dried fermented sample was 25.43% and that of the autoclaved fermented sample was 14.06% while 37.55% was for the untreated fermented sample. The reduction in carbohydrate levels agrees with the work of Oyewole and Odunfa (1989) that carbohydrate level during fermentation decreases because of the activities of the fermenting microbes.

This reduction in carbohydrate level is usually as a result of saccharolytic enzymes secreted by the fermenting organisms. These enzymes must have broken down the complex carbohydrates into smaller units like sugars and alcohols. For instance, *Saccharomyces cerevisiae* which is common to all the samples, produce enzymes important in their inverting and fermentative properties. The enzymes include sucrase, maltase, lactase, hexophosphatase, reductase, carboxylase, milibiase, and endo-tryptase, as well as proteolytic enzymes. *Rhizopus nigricans,* which is also common to all the fermented samples, has been shown to secrete amylase, a starch degrading enzyme (Ayogu and Amadi, 2010).

There was a decrease in the crude protein level in all the fermented samples compared to the raw sample. The unfermented raw sample had a mean crude protein of 16.09% while the oven dried fermented, autoclaved fermented and untreated fermented samples recorded mean protein level of 14.87, 11.19 and 10.83%, respectively.

The reduction may be as a result of proteolytic enzymes produced by the fermenting organisms. Apart from the fact that *Saccharomyces cerevisiae* does, members of the genus Rhizopus are also known to produce proteases (Heskamp and Barz, 1998). These enzymes may have broken down the proteins into peptides, amino acids or other nitrogenous compounds. Though reduced, the protein levels obtained in the samples still compare favourably with those obtained by Mbata et al. (2009).

There was an increase in fat content (ether extractive) in all the fermented samples. The mean fat content for the autoclaved fermented, oven dried fermented and untreated fermented samples were 11.19, 27.44 and

Table 3. Proximate analysis of peanut and popcorn samples (%).

Treatment	Composite	MC	CP	EE	ASH	NFE	CF	GE (Kcal/100 g)
Oven dried, fermented	PNF 7.5 g + PCF22.5 g	28.77	16.20	31.60	1.35	15.64	6.41	455.10
	PNF 15 g + PCF 15 g	27.27	10.28	27.47	0.85	29.18	4.95	436.30
	PNF 22.5 g + PCF 7.5 g	20.64	18.13	22.65	1.05	31.48	6.05	444.40
Autoclaved, fermented	PNF 7.5 g + PCF 22.5 g	17.93	7.92	33.10	1.54	30.47	4.15	481.50
	PNF 15 g + PCF 15 g	33.07	9.11	42.20	1.79	5.04	8.79	472.90
	PNF 22.5 g + PCF 7.5 g	30.68	16.56	40.20	0.95	6.69	4.92	503.10
Untreated, fermented	PNF 7.5 g + PCF 22.5 g	15.38	10.43	22.60	1.55	44.31	5.73	451.40
	PNF 15 g + PCF 15 g	12.82	13.51	32.10	1.50	31.27	8.80	507.03
	PNF 22.5 g + PCF 7.5 g	18.96	8.57	31.46	0.59	37.08	3.34	496.04
Raw, unfermented	Defatted peanut	4.49	24.69	1.01	4.54	61.06	4.21	394.56
	Popcorn flour	10.72	7.49	5.05	0.75	74.06	1.48	391.18

MC= Moisture content (%), CP = crude protein content (%), EE = crude fat, as “ether extractives”, ASH=ash content, NFE= nitrogen free extractives (or Carbohydrates by Difference), CF= crude fibre content.

28.72%, respectively. These values increased markedly when compared to those of the raw unfermented samples (1.01 and 5.50%). The fat content variation could be due to the fact that some if not all of the microorganisms involved in the fermentation process contained some lipids in their structure, so as they proliferate, lipids are released into the substrate.

The mean ash content in the oven dried fermented, autoclaved fermented and untreated fermented samples were 1.08, 1.43 and 1.21%, respectively. These values were less than that of the raw unfermented sample with a mean value of 2.65%. Since the ash content is a measure of the total amount of minerals present within a food, a reduction in its level during microbial fermentation could be as a result of the minerals being used up by the fermenting organisms as a mineral source during their metabolism (Aderiye and Ogunjobi, 1998).

Contrary to the 4.21 and 1.48% crude fibre values in the unfermented raw peanut and popcorn flours respectively, the oven dried fermented sample had a mean crude fibre value of 5.80% while the autoclaved fermented and the untreated fermented samples had 5.95% each. There was no significant difference in the crude fibre content.

The mean moisture content in the oven dried fermented, autoclaved fermented and untreated fermented samples were 25.56, 27.22 and 15.72% as against 4.49 and 10.72% in the defatted peanut and popcorn flours, respectively. The increase in the moisture content could be attributed to the addition of water to the composite flours prior to fermentation.

The gross energy in the oven dried, autoclaved and untreated samples were between 436.3 and 455.1, 472.9 and 503.1, and 451.4 and 507.03 kcal/100 g, respectively. This is similar to and even surpasses the value obtained by Aletor and Ojelabi (2007) in the analysis of ‘donkwa’, a maize-peanut ball.

The mineral analysis result of both the raw unfermented samples of peanut and popcorn flours and the fermented composite flour samples are shown in Table 4. The level of potassium in all the samples increased markedly. The mean level in the oven dried fermented, autoclaved fermented and untreated fermented samples were 398.67, 440.67 and 387.33, respectively.

Lower levels of phosphorus were recorded for the fermented samples which were lower than that of the unfermented raw sample. The levels obtained still compared favourably with the values obtained by Aletor and Ojelabi (2007) in their analysis of some traditional Nigerian snacks.

Although, needed to maintain water balance within cells and in the function of both nerve and muscles impulses, high level of sodium in foods may lead to edema, development of high blood pressure and risk of osteoporosis in women. The result of the mineral analysis shown in Table 4 revealed that sodium levels in the autoclaved samples reduced after fermentation (90.33 ppm). There was however increase in the levels of sodium in other samples but still fell within the dietary limit recommended by World Health Organisation.

There were marked reduction in the levels of magnesium and calcium in all the samples. The reduction in these minerals could be as a result of their utilization by the fermenting microorganisms as reported by Aderiye and Ogunjobi (1998).

The results of the antinutrient analysis of the samples are presented in Table 5. Phytic acid is naturally present in many foods especially cereals and legumes. When above a certain level phytate reduce the bioavailability of

Table 4. Mineral analysis of peanut and popcorn samples (ppm).

Treatment	Composite	Na	K	Mg	Ca	P
Oven dried fermented	PNF 7.5 g +PCF 22.5 g	88.00	528.00	35.00	38.00	205.00
	PNF 15 g +PCF 15 g	112.00	293.00	37.00	19.00	224.00
	PNF 22.5 g +PCF7.5 g	71.00	375.00	42.00	35.00	186.00
Autoclaved fermented	PNF 7.5 g +PCF22.5 g	256.00	462.00	22.00	44.00	322.00
	PNF 15 g +PCF 15 g	188.00	512.00	24.00	28.00	275.00
	PNF22.5 g +PCF7.5 g	162.00	348.00	32.00	29.00	220.00
Untreated fermented	PNF 7.5 g +PCF22.5 g	206.00	479.00	21.00	26.00	216.00
	PNF 15 g +PCF 15 g	129.00	403.00	31.00	22.00	220.00
	PNF22.5 g +PCF7.5 g	200.00	280.00	30.00	24.00	188.00
Raw, unfermented	Defatted peanut flour	189.20	152.00	101.20	75.10	380.00
	Popcorn flour	103.89	112.01	89.13	60.00	300.00

PNF= Peanut flour, PCF= popcorn flour.

Table 5. Antinutrient analysis of peanut and popcorn samples (ppm).

Treatment	Composite	Phytate	Oxalate	Tannin
Oven dried, fermented	PNF 7.5 g +PCF 22.5 g	0.49	3.60	3.28
	PNF 15 g +PCF 15 g	0.57	5.67	1.64
	PNF 22.5 g +PCF 7.5 g	0.74	5.13	1.00
Autoclaved, fermented	PNF 7.5 g +PCF 22.5 g	0.74	1.98	2.27
	PNF 15 g +PCF 15 g	1.24	1.44	1.59
	PNF 22.5 g +PCF 7.5 g	0.41	1.44	1.58
Untreated, fermented	PNF 7.5 g +PCF 22.5 g	0.66	5.76	1.38
	PNF 15 g +PCF 15 g	0.66	2.20	2.30
	PNF 22.5 g +PCF 7.5 g	0.66	6.93	1.75
Raw, unfermented	Defatted peanut flour	1.35	2.94	2.50
	Popcorn flour	1.25	2.70	2.58

PNF= Peanut flour, PCF= popcorn flour.

minerals and solubility, functionality and digestibility of proteins (Reddy and Pierson, 1994). There was significant reduction in the phytate level in all samples. A wide range of microflora has been known to possess phytase activity (Ojokoh, 2005) which may be partly responsible for reduction in phytic acid content in the fermenting samples.

There was a decrease in oxalate level in the oven dried fermented sample compared with other samples where there were some increase. This may be due to the processing that the samples were subjected to and coupled with activities of the microorganisms.

Tannins, when in association with proteins, can cause inactivation of digestive enzymes and reduce protein digestibility. All the samples that were untreated before fermentation showed a reduction in tannin level. The level ranged from 1.38 to 2.30 as against 2.50 and 2.58 in the unfermented samples. The oven treated and autoclaved samples also showed significant reduction in tannin level except where the level of the corn flour was high, 25 g. This may suggest that the bran of the popcorn seeds used had a high level of tannins as reported by Reddy and Pierson (1994) that tannins are concentrated in the bran fraction of cereals. Similar reduction in tannin of fermented products includes Jack beans (Odetokun, 2000) and African oil bean seed (Enujiugha and Akanbi

2005).

Conclusion

The study therefore reveals that fermentation can enhance the nutritional quality of popcorn and peanut composite flour positively.

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