

Research Article

Oluwaseun P. Bamidele*, Beatrice M. Fasogbon

Nutritional and functional properties of maize-oyster mushroom (*Zea mays-Pleurotus ostreatus*) based composite flour and its storage stability

<https://doi.org/10.1515/opag-2020-0007>

received July 7, 2019; accepted October 28, 2019

Abstract: The over reliance on starchy foods such as maize flour may lead to protein energy malnutrition (PEM) in children. The enrichment of maize with protein-rich oyster mushroom will improve the nutritional composition of maize flour. This study determined the effects of oyster mushroom flour on nutritional, functional and storage stability properties of composite flour containing maize and oyster mushroom. Oyster mushroom flour was added at 0, 5, 10 and 15% to maize flour. Proximate, functional, minerals, amino acid profile, free fatty acids and peroxide value of the composite flours were determined. An increase in the addition of oyster mushroom flour led to an increase in proximate and the minerals content of the composite flour, but the functional properties decreased. Oyster mushroom flour increased the amino acid profile of the composite flour, with leucine being the highest (26.3 mg/g). The flours were relatively stable (25°C) during storage. Enriching maize flour with 15% oyster mushroom flour improved the nutritional quality of maize flour which makes the resulting composite flour a better raw material for human consumption.

Keywords: Stable food; Enrichment; Oyster; Maize flour; Protein-Energy nutrition; Storage

1 Introduction

Malnutrition remains a major health and economic burden in sub-Saharan Africa with the region being home to some of the world's most nutritionally insecure people (Bain et

al. 2013). The dual existence of over-nutrition including obesity and undernutrition such as Protein-Energy Malnutrition (PEM) and micronutrient deficiencies within the same household is a major cause of concern (Tzioumis and Adair 2014).

The indigenous staples of most households in sub-Saharan Africa are starch-based with little or no source of other macro and micronutrients (Tzioumis and Adair 2014). The over-reliance on starch-dense staples such as maize to provide all nutritional requirements leads to widespread dietary micronutrient deficiency (Zuma et al. 2018) and PEM. Micronutrient deficiency has a detrimental effect on growth and development in children and childbearing women (Bain et al. 2013). In addition to this is PEM caused by an inadequate intake of protein and/or calories (WHO 2006)

Several solutions through concerted research efforts have been proposed to address the problem of PEM and micronutrient deficiencies. Some of these solutions include the fortification of starch staples with legumes. Maize flour has been fortified with soybean flour (Abiose et al. 2015), groundnut flour (Temba et al. 2017) and mushroom flour (Ishara et al. 2018) respectively. Mushrooms have been found to contain higher protein, minerals, and vitamins (Sanchez 2004) than grains which can improve the nutritional composition of maize flour.

Edible mushrooms such as oyster mushroom have been used as food supplements in different African communities for a long time (Valverde et al. 2015). The presence of micronutrients such as iron, zinc, vitamins that are crucial for various functions in the human body makes mushrooms a valuable food source. Mushrooms are low in fat, high in protein with good biological value and phytochemicals, thus are considered as the next generation of health food due to these nutritional properties (Arora et al. 2017). Fortifying maize flour with oyster mushroom (*Pleurotus ostreatus*) flour can improve the nutritional composition of maize flour.

Nutritionally balanced food at affordable cost is a prime concern in attaining food and nutritional security

*Corresponding author: Oluwaseun P. Bamidele, Department of Food Technology, Federal Polytechnic Offa, Kwara State, Nigeria, Tel. +2348032732412, E-mail: bampet2001@yahoo.co.uk

Beatrice M. Fasogbon, Department of Food Technology, Federal Institute of Industrial Research, Oshodi, Lagos State, Nigeria

of rural population in the world. In order to achieve this goal, mushroom flour will be used to enhance the nutritional properties of maize (a staple food with some limiting nutritional properties). Hence, the study on maize flour fortified with oyster mushroom is worth doing and useful. Authors have elaborately analyzed the nutritional, functional and storage stability properties maize-oyster mushroom composite flour blends.

2 Materials and methods

2.1 Materials

Maize flour was purchased from a retail market in Ile-Ife, Osun State, Nigeria. Fresh mushroom (*P. ostreatus*) was procured from a commercial mushroom farm at Ibadan, Oyo state, Nigeria.

2.2 Methods

2.2.1 Mushroom flour processing

About 1% potassium metabisulfite ($K_2S_2O_5$) was used to pretreat (10 min at 40°C) oyster mushroom fruit to prevent browning and dried at 60°C for 10 h in a hot air oven (LEEC, Ltd., Nottingham, UK) according to the modified method of Parab et al. (2012). The dried mushroom was ground, sieved using 500 μ m mesh size and stored in a polyethylene bag and refrigerated at 4°C for further analysis.

2.2.2 Preparation of flour blends

Flour blends [ratio of maize flour (*MaF*) to mushroom flour (*MF*)] were carried out in the laboratory. The flour samples (maize, and mushroom) were weighed and mixed using a kitchen size mixer (Kitchen Aid mixer, model ksm 103, USA). The samples were control maize and mushroom flour, 95% maize flour and 5% mushroom flour, 90% maize flour and 10% mushroom flour, and 85% maize flour and 15% mushroom flour. The fortified flour and the controls were put in a polyethylene bag and stored at a refrigerating temperature (4°C) for further analyses.

2.2.3 Proximate composition of maize and oyster mushroom flour and their blends

The method of AOAC (2000) was used to determine moisture content, crude protein, crude fat, ash, and crude fiber of the raw and the flour blends. Carbohydrate contents were calculated by subtracting the moisture, protein, ash and fat percentage from 100%. The energy content of both the raw and the blend flour was determined by Atwater component (carbohydrate and protein values were multiplied by 4 kcal/g each, whereas fats values were multiplied by 9 kcal/g. The three values were added to give the energy content of the samples).

2.2.4 Functional properties of maize and oyster mushroom flour and their blends

The functional properties (water absorption capacity, swelling power, and bulk density) of the samples were determined by the modified method of Bamidele et al. (2015). Water absorption capacity, 2 g of the sample (W_1) was measured into a centrifuge tube and 30 ml of hot water was added at 70°C. The sample was vortexed for 10 min and allowed to rest for 10 min. The suspension was centrifuged at 4100 X g for 15 min at 25°C. The supernatant was decanted and the tube containing the residue was weighed (W_2).

$$\text{Water absorption} = \frac{W_2 - W_1}{\text{Weight of the sample}}$$

The swelling power of the sample was determined by the modified method of Bamidele et al. (2015). 2 g of the sample was weighed into the centrifuge tube and 30 ml of water was added. The slurry that formed was heated at 70°C for 15 min in water bath. Cooled slurry was placed in a centrifuge at 4100 X g for 15 min at 25°C. The supernatant was decanted and the centrifuge tube that contained the residue alone was dried in a hot air oven (50°C) for 30 min and weighed. For the bulk density determination, exactly 10 g of the sample was weighed into 25 ml graduated cylinder, the cylinder was gently tapped on the laboratory bench until no change in volume. The final volume of the sample was recorded and the difference in the initial volume and the final volume was determined and expressed as the bulk density in g/ml.

2.2.5 Mineral analysis of maize and oyster mushroom flour and their blends

Mineral contents (calcium, potassium, sodium, iron, magnesium and phosphorous) of the control (maize flour and mushroom flour) and the formulated flours were determined. The AOAC (2000) method was used to determine the minerals. Ash dissolved in concentrated nitric acid, with 50 ml of deionized water was analyzed using an atomic absorption spectrophotometer (GBC 904AA; Germany). A flame photometer was used to determine the sodium and potassium content of the samples. Phosphorus was determined using UV-spectrophotometer. The complex formed (ammonium vanadate molybdate) was read at 450 nm.

2.2.6 Amino acid profile of maize and oyster mushroom flour and their blends

The modified method of Kaga et al. (2002) was used to determine the amino acids content of the samples. The amino acids content of composite flour samples was analyzed on Technicon sequential multisample (TSM). Briefly, defatted fortified and non-fortified flour were hydrolyzed with HCl under vacuum in a sealed pyrex tube for 24 h. The hydrolyzed sample was cooled and filtered, after which it was dried at 40°C. About 5 mL of acetate buffer (pH 2.0) and 5 to 10 µL was used to dilute the filtrate before loaded into the TSM amino acid analyzer. The peak area was calculated as the concentration of each amino acid.

2.2.7 Fatty acid profile of maize and oyster mushroom flour and their blends

The fatty acid profile of the maize flour blend with oyster mushroom was determined with the help of Gas liquid Chromatograph (Omega-Wax Capillary Supelco, USA). The mixture of n-hexane, ethyl ether and acetic acid (70:28:2) was used as a mobile phase in thin layer chromatography with silica gel G60 (Merck, Darmstadt, Germany) to separate the fatty acid composition in the blends

2.2.8 Storage stability of maize and oyster mushroom flour and their blends

The storage stability of the flour (maize flour, oyster mushroom flour, and the fortified flour) was studied. About 100

g of flour was packed in polyethylene bags and placed on the shelf at ambient temperature (25°C). During storage, changes in free fatty acids and peroxide values were analyzed at 2 weeks interval for 12 weeks of storage.

2.2.8.1 Free fatty acids of stored maize and oyster mushroom flour and their blends

The free fatty acids of the flour sample were determined by the ISO (1998) method. About 5 g of the flour was mixed with ethanol/water (95:5) and continuously shaken for 1 h in a shaker at 40 rpm. After shaking, the samples were centrifuged for 15 min (4°C) at 12,000 g. The supernatant collected from the centrifuged sample was transferred into a conical flask, 5 drops of phenolphthalein indicator were added and titrated against 0.05 M NaOH until the colour turned light pink.

2.2.8.2 Peroxide value of stored maize and oyster mushroom flour and their blends

Peroxide values of the oil extracted from the flour (maize and oyster mushroom flour) by petroleum ether were determined as described in the methods of AOAC (2000). Exactly 5 g sample of oil was weighed into a 250 ml Erlenmeyer flask and then 30 ml acetic acid chloroform solution (3:2) solution was added. The flask was swirled until the sample was dissolved and 0.5 ml of saturated potassium iodide (KI) solution was also added. The solution was allowed to stand with occasional swirling for 1 min and then 30 ml distilled water was added. The solution was titrated with 0.01 N sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) until the color changed to light yellow. Exactly 0.5 ml of 1% soluble starch indicator was added. The blue solution formed was titrated with more sodium thiosulfate until the blue colour disappeared.

$$\text{Peroxide value (meq } \left(\frac{\text{PV}}{\text{kg}}\right) \text{ sample)} = \frac{S \times N \times 1000}{\text{Weight of sample}}$$

Where S = ml of $\text{Na}_2\text{S}_2\text{O}_3$ and N = 0.01 sodium thiosulfate

2.3 Statistical analysis

All data obtained were subjected to analysis of variance (ANOVA) using the Statistical Package for Social Science (SPSS; version 21). Significant means were separated using Duncan's multiple comparison tests at 5% level of probability.

3 Results and Discussion

3.1 Proximate composition of maize and oyster mushroom flour and their blends

The proximate composition and energy content of the 100% maize flour, 100% mushroom flour, and their blends are presented in Table 1. Moisture content values of 9.3% and 7.5% were recorded for 100% maize flour and 100% mushroom flour respectively, while moisture content ranged from 8.2 to 8.3% for the blends. The moisture content in the flour blends was not significantly ($p < 0.05$) different. Shahzadi et al. (2005) reported that flour-based food products with less than 13% of moisture content are more stable from auto-oxidation or moisture-dependent deterioration, especially during flour storage.

Mushroom flour showed higher (approx. 3 times) protein content than the maize flour (Table 1). The addition of mushroom flour to the maize resulted in a substantial increase in the protein contents of the flour blends. The protein content of the maize flour containing 5, 10 and 15% mushroom increased by approximately 28, 49 and 83%, respectively. The increase in protein content is expected since the mushroom flour had high amounts of protein compared to the maize flour.

This agrees with reports of Arora et al. (2017) who reported a 17.3% increase in the protein content of noodles made from wheat and oyster mushroom flour. Studies by Farzana et al. (2017) showed an increase in protein (13.63%) content in vegetable soup powder supplemented with mushroom, soy flour and moringa leave powder when compared with the protein (6.92%) vegetable soup without the supplements. It could be suggested that the

addition of mushroom flour to maize flour has a great potential in combatting protein-calorie malnutrition in sub-Saharan Africa. It could also be a cheap source of protein for people in developing countries.

The crude fat content of the control samples (Maize flour and mushroom flour) is 1.3% and 1.6% respectively. There was a significant difference in the crude fat content of the control flours. Fat content usually plays a role in the stability of flour particularly during lipid-peroxidation. The fat content of the blends was between 1.4 – 1.5%. The relatively low-fat content of the flour blends could make them a potential raw material in the formulation of a variety of food products for the obese.

The ash contents of flour blends increased (45.5, 100 & 236%) as the percentage of mushroom flour in maize flour increased. This observation agrees with the report of Ishara et al. (2018). The authors reported 1.33% ash content for maize flour and 8.56% ash content for oyster mushroom flour. They also reported an increase in ash content of the flour blends between maize flour and mushroom flour. The crude fiber contents in maize flour (1.1%) and mushroom flour (5.7%) were significantly ($p > 0.05$) different. The crude fiber content of the flour blend increased (36.4, 90.9 & 227.2%) as the amount of mushroom flour added increases. Mushroom flour is known to have a high amount of dietary fiber which aids digestion in the human body (Cheung 2013). This indicates that the flour blends may be a good source of dietary fiber. Carbohydrate content gradually decreased (2.6, 6.0 & 13.1%) with the increasing inclusion of mushroom flour in maize flour. The highest carbohydrate content (78.9%) was observed in 100% maize flour and lowest in 100% mushroom flour (59.4%). The energy content of the flour blends

Table 1: Proximate composition of maize (*Zea mays*) flour composited with mushroom (*Pleurotus ostreatus*) flour at different ratio (%)

Samples (%)	Moisture	Protein	Crude fat	Ash	Crude fiber	Carbohydrate	Energy kcal/100g
100 MaF	9.3 ^c ±0.1	8.3 ^a ±0.4	3.3 ^a ±0.1	1.1 ^a ±0.1	1.1 ^a ±0.1	76.9 ^e ±0.8	370.5
100MF	7.5 ^a ±0.1	20.4 ^e ±0.3	1.6 ^d ±0.1	5.4 ^e ±0.2	5.7 ^e ±0.1	59.4 ^a ±0.5	333.6
95MaF + 5 MF	8.3 ^b ±0.2	10.6 ^b ±0.2	3.1 ^a ±0.1	1.6 ^b ±0.1	1.5 ^b ±0.2	74.9 ^d ±0.6	369.9
90 MaF + 10MF	8.3 ^b ±0.3	12.4 ^c ±0.1	2.7 ^b ±0.2	2.2 ^c ±0.1	2.1 ^c ±0.1	72.3 ^c ±0.5	363.1
85MaF + 15MF	8.2 ^b ±0.3	15.2 ^d ±0.3	2.5 ^b ±0.2	3.7 ^d ±0.2	3.6 ^d ±0.1	66.8 ^b ±0.6	350.5

Values are means and standard deviation of three determinations (n=3); Means followed by the same letter within the same column are not significantly ($p > 0.05$) different according to LSD test

MaF is maize flour, MF is mushroom flour

was between 345.5 kcal/g and 361.4 kcal/g. The high-energy content of the flour blends may be advantageous in the formulation of breakfast cereal and complementary foods.

3.2 Functional properties of maize and oyster mushroom flour and their blends

The functional properties of the control samples (100% maize and mushroom flour) and their blends are shown in Table 2. The functional properties of the flours determine their food application and end use. The 100% maize flour had the highest water absorption capacity (WAC) value (4.5 g/ml), while the WAC of 100% mushroom flour was the least (2.4 g/ml). WAC of the flour blends decreased (8.9, 26.7 & 35.6%) with an increase in the addition of mushroom flour in maize flour. WAC is an indication of how food material will absorb water during processing and the absorption power of food material depends on carbohydrate polymer or the amount of native starch in such food product (Falade and Okafor 2013). The decrease recorded in the flour blends may be due to the presence of non-starch polysaccharides such as chitin, α - and β -glucan and hemicellulose in an oyster mushroom that may have competed with starch for available water thus reducing the ability of starch to absorb water (Foschia et al. 2015).

The swelling power (SP) of the samples followed the same pattern as the WAC. 100% maize flour had the highest value (7.2 g/ml) and 100% mushroom flour with the least (2.9 g/ml). The SP of the flour blends (Maize and mushroom flour) significantly ($p > 0.05$) decreased (4.2, 29.2 & 41.7%) with an increase in the amount of mushroom added. The flour blend with 5% mushroom flour had the highest SP value amongst the blends (6.9

g/ml), while flour blends with 15% mushroom flour had the least value (4.2 g/ml). The decrease observed in the flour blends (Maize flour and oyster mushroom flour) may be attributed to the addition of oyster mushroom flour which contain non-soluble dietary fiber and a lower or no amount of starch (Aishah and Rosli 2013; Deepalakshmi and Mirunalini 2014).

The bulk density value of the control samples (100% maize and oyster mushroom flour) are shown in Table 2. The 100% maize flour had the highest value (1.8 g/ml) while the 100% oyster mushroom flour had the least value (0.8 g/ml). The bulk density of the blends significantly ($p < 0.05$) decreased (38.9, 44.4 & 50%) with an increase in the addition of mushroom flour. Bulk density depends on the heaviness of the solid particles present in the food materials. It helps to determine types of packaging requirements, material handling and application in the food industry (13). The decrease observed in the bulk density of the blends may be attributed to the addition of oyster mushroom flour to maize flour as mushroom flour contained lower amount of starch. Also, the presence β -glucan, which is the most abundant polysaccharide present in mushroom has been attributed with a reduction in bulk density when compared with maize flour which contains starch (amylose and amylopectin) as polysaccharide (Jantaramanant et al. 2014).

3.3 Mineral content of maize and oyster mushroom flour and their blends

The mineral composition of 100% maize and oyster mushroom flour and their blends are shown in Table 3. The level of major elements (potassium, sodium, magnesium, and phosphorus) was high in oyster mushroom flour (256.4, 41.2, 32.3, and 224.6 mg/100 g) compared to 100% maize

Table 2: Functional properties of maize (*Zea mays*) flour composited with mushroom (*Pleurotus ostreatus*) flour at different ratio (g/ml)

Samples (%)	Water Absorption Capacity	Swelling Capacity	Bulk density
100MaF	4.5 ^e ± 0.4	7.2 ^d ±0.3	1.8 ^d ±0.1
100MF	2.4 ^a ± 0.1	2.9 ^a ±0.1	0.8 ^a ±0.2
95 MaF + 5 MF	4.1 ^d ±0.2	6.9 ^c ±0.3	1.1 ^c ±0.2
90 MaF + 10MF	3.3 ^c ±0.2	5.1 ^c ±0.5	1.0 ^b ±0.2
85 MaF + 15 MF	2.9 ^b ±0.1	4.2 ^b ±0.2	0.9 ^b ±0.2

Values are means and standard deviation of three determinations (n=3); Means followed by the same letter within the same column are not significantly ($p > 0.05$) different according to LSD test

MaF is maize flour, MF is mushroom flour

Table 3: Mineral content of maize (*Zea mays*) flour composited with mushroom (*Pleurotus ostreatus*) flour at different ratio (mg/100g)

Samples (%)	Calcium	Potassium	Sodium	Iron	Zinc	Magnesium	Phosphorus
100 MaF	62.5 ^b ±0.5	76.6 ^a ±0.5	28.6 ^a ±0.3	3.5 ^b ±0.4	2.2 ^a ±0.2	25.4 ^a ±0.5	192.6 ^a ±0.5
100MF	5.6 ^a ±0.3	256.4 ^e ±1.3	41.2 ^e ±0.2	2.5 ^a ±0.4	4.9 ^e ±0.1	32.3 ^d ±0.2	224.6 ^e ±0.4
95 MaF + 5 MF	62.7 ^b ±0.4	89.7 ^b ±0.4	30.4 ^b ±0.5	3.6 ^b ±0.5	2.9 ^b ±0.3	28.5 ^b ±0.5	201.6 ^b ±0.4
90 MaF + 10 MF	63.2 ^b ±0.6	94.8 ^c ±0.7	32.6 ^c ±0.3	3.7 ^b ±0.4	3.1 ^c ±0.3	29.7 ^c ±0.4	210.6 ^c ±0.3
85 MaF + 15 MF	64.8 ^b ±0.4	102.9 ^d ±0.6	36.1 ^d ±0.4	3.9 ^b ±0.4	3.8 ^d ±0.5	31.9 ^d ±0.6	214.9 ^d ±0.5

Values are means and standard deviation of three determinations (n=3); Means followed by the same letter within the same column are not significantly ($p>0.05$) different according to LSD test

MaF is maize flour, MF is mushroom flour

flour (76.6, 28.6, 25.4, and 192.6 mg/100 g). The trace element (iron and zinc) in both samples (100% maize and oyster mushroom flour) showed that iron content in maize flour was higher (3.5 mg/100g) than oyster mushroom flour (2.5 mg/100g). Also, the zinc content of oyster mushroom flour was higher (4.9 mg/100g) than maize flour (2.2 mg/100 g). The high content of minerals present in the 100% oyster mushroom could be related to the high ash content of the sample (Table 1), which increases as the mushroom flour of the formulated samples increases. The mineral content of food samples is determined through the ash content of such food.

The flour blends (i.e. the mixture of maize flour with oyster mushroom flour) showed an increase in all the mineral contents as the amount of oyster mushroom flour added increased. The increase may be attributed to a high amount of the mineral in the oyster mushroom which enhanced the number of minerals in the blend samples. Mushroom flour has been reported to be high in minerals and has health-promoting properties (Valverde et al. 2015). In view of the importance of these minerals, the blends of maize flour with oyster mushroom flour make good composites that can promote good health when consumed, especially in households or when used as a raw material in the formulation of nutritious snacks.

3.4 Amino acid profile of maize and oyster mushroom flour and their blends

Table 4 shows the amino acid composition of 100% maize and oyster mushroom flour and their blends. There was a significant difference ($p < 0.05$) in the distribution of all the amino acids in the samples including the formulated samples. Lysine, leucine, aspartic acid, glutamic acid, alanine, and arginine were the most abundant amino acids in the two flour samples (maize and mushroom flour).

However, the number of amino acids in 100% mushroom flour was higher than 100% maize flour. Tryptophan, methionine, and cystine were the lowest amino acids in 100% maize flour (0.9, 0.9 and 0.7 mg/g respectively) and in 100% oyster mushroom flour with values of 5.2, 4.1 and 3.2 mg/g respectively. Aspartic and glutamic acids were high in 100% maize flour and 100% oyster mushroom flour. The observed high levels of these amino acids may be attributed to their use as a precursor from which the backbone of other amino acids is formed (Oyetayo et al. 2007). There was an increase in the number of amino acids present in the blend sample with the increase in the addition of oyster mushroom flour. This was expected as oyster mushroom flour has a higher amino acid content.

In this study, leucine was the most abundant essential amino acid in both 100% maize flour (8.6 mg/g) and the 100% mushroom flour (26.3 mg/g). Leucine was also high in all the formulated samples (9.6 mg/g in the sample that contained 5% oyster mushroom flour, 10.2 mg/g in samples that contained 10% oyster mushroom flour and 12.6 mg/g in the sample that contained 15% oyster mushroom flour). This result is in line with the report of Oyetayo et al. (2007) that mushroom flour is a rich source of leucine and lysine.

3.5 Fatty acid profile of maize and oyster mushroom flour and their blends

Table 5 shows the fatty acid profile of maize and oyster mushroom flour and their blends. The two flours (maize and oyster mushroom) contained saturated fatty acids such as: palmitic acid (C16:0), stearic acid (C18:0), monounsaturated fatty acid (oleic acid (C18:1)), and polyunsaturated fatty acids (linoleic acid (C18:2) and linolenic acid (C18:3)). Monounsaturated fatty acid (oleic acid) was the highest in maize (42.41 mg/g) flour and oyster mush-

Table 4: Amino acid profile of maize (*Zea mays*) flour composited with mushroom (*Pleurotus ostreatus*) flour at different ratio (mg/g)

Amino acids	100 % MaF	100% MF	95% MaF:5%MF	90% MaF:10% MF	85% MaF:15% MF
Tryptophan	0.9 ^a ±0.1	5.2 ^e ±0.2	1.5 ^b ±0.1	2.1 ^c ±0.1	3.2 ^d ±0.1
Threonine	2.1 ^a ±0.2	18.4 ^d ±0.3	3.6 ^b ±0.2	4.2 ^c ±0.2	4.9 ^c ±0.2
Isoleucine	2.5 ^a ±0.1	16.9 ^d ±0.3	3.2 ^b ±0.2	3.9 ^b ±0.3	4.5 ^c ±0.2
Valine	3.1 ^a ±0.1	22.2 ^d ±0.4	4.5 ^b ±0.1	5.1 ^c ±0.1	5.9 ^c ±0.2
Lysine	1.8 ^a ±0.1	23.2 ^d ±0.3	2.3 ^b ±0.2	3.1 ^c ±0.2	3.8 ^c ±0.1
Methionine	0.9 ^a ±0.1	4.1 ^d ±0.1	1.1 ^b ±0.1	1.9 ^c ±0.2	2.4 ^d ±0.1
Phenylalanine	3.5 ^a ±0.2	16.8 ^c ±0.3	4.2 ^b ±0.2	5.1 ^c ±0.1	6.5 ^d ±0.3
Histidine	2.1 ^a ±0.1	13.1 ^d ±0.5	3.0 ^b ±0.1	3.9 ^b ±0.3	4.6 ^c ±0.1
Leucine	8.6 ^a ±0.3	26.3 ^c ±0.3	9.6 ^b ±0.2	10.2 ^c ±0.2	12.6 ^d ±0.3
Aspartic acid	6.2 ^a ±0.2	32.2 ^e ±0.2	8.1 ^b ±0.3	9.5 ^c ±0.2	10.6 ^d ±0.3
Glutamic acid	5.7 ^a ±0.2	54.2 ^e ±0.5	6.6 ^b ±0.1	7.8 ^c ±0.3	8.8 ^d ±0.2
Glycine	2.5 ^a ±0.1	18.1 ^c ±0.3	3.6 ^b ±0.2	4.2 ^c ±0.1	5.2 ^d ±0.3
Alanine	1.7 ^a ±0.1	27.9 ^e ±0.3	2.5 ^b ±0.3	3.5 ^c ±0.3	4.6 ^d ±0.1
Cystine	0.7 ^a ±0.1	3.2 ^d ±0.1	0.9 ^a ±0.1	1.2 ^b ±0.1	1.9 ^c ±0.1
Arginine	3.8 ^a ±0.1	26.8 ^c ±0.3	4.9 ^b ±0.2	6.1 ^c ±0.3	7.2 ^d ±0.3
Serine	1.8 ^a ±0.1	18.5 ^e ±0.3	2.6 ^b ±0.2	3.9 ^c ±0.3	4.8 ^d ±0.1
Proline	1.2 ^a ±0.1	16.1 ^c ±0.2	2.4 ^b ±0.1	3.4 ^c ±0.1	4.2 ^d ±0.2
Tyrosine	2.7 ^a ±0.2	12.9 ^e ±0.5	3.1 ^b ±0.2	4.1 ^c ±0.2	5.2 ^d ±0.2
Total EAA	25.5 ^a ±0.3	119.9 ^e ±1.2	23.4 ^b ±0.3	29.3 ^c ±0.3	35.8 ^d ±0.6
Total Amino Acid	51.8 ^a ±0.5	356.1 ^e ±2.5	67.7 ^b ±0.3	83.2 ^c ±0.3	100.9 ^d ±1.0

Value are mean and SD of three determination (n=3). Mean followed by the same letter within the same row are not significantly (p < 0.05) different according to LSD Test. MaF is maize flour, MF is mushroom flour.

Table 5: Fatty acids profile (mg/g) of maize and oyster mushroom flour and their blends

Samples	Fatty acid Profile				
	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid
100 MaF	10.6 ^c ±0.3	5.8 ^b ±0.3	42.4 ^b ±0.5	23.6 ^b ±0.4	20.1 ^c ±0.3
100MF	0.2 ^a ±0.2	0.2 ^a ±0.1	0.4 ^a ±0.1	0.3 ^a ±0.2	0.3 ^a ±0.1
95 MaF+5 MF	10.2 ^c ±0.3	5.7 ^b ±0.3	42.3 ^b ±0.3	23.3 ^b ±0.4	20.2 ^c ±0.2
90MaF+10 MF	9.5 ^b ±0.2	5.4 ^b ±0.5	42.1 ^b ±0.4	22.9 ^c ±0.3	19.8 ^b ±0.3
85MaF+15 MF	9.2 ^b ±0.3	5.3 ^b ±0.1	42.0 ^b ±0.3	22.6 ^c ±0.2	19.6 ^b ±0.2

Value are mean and SD of three determination (n=3). Mean followed by the same letter within the same row are not significantly (p < 0.05) different according to LSD Test. MaF is maize flour, MF is mushroom flour.

room (0.42 mg/g) flour, followed by polyunsaturated fatty acids (23.64 mg/g for linoleic acid and 20.10 mg/g for linolenic acid) in maize flour. In oyster mushroom flour, poly-

unsaturated fatty acids were also higher with 0.29 mg/g for linoleic acid and 0.31 mg/g for linolenic acid.

The fatty acid profile of maize flour was higher than that of oyster mushroom in all the compositions. This can

be attributed to the quantity of fat (3.3%) present in maize flour compared to oyster mushroom flour (1.6%). The flour blends have fatty acid compositions that were similar to that of maize flour and higher than oyster mushroom flour. The high quantity of polyunsaturated fatty acids (linoleic and linolenic acid) found in the blend samples are desirable because of the health benefits of polyunsaturated fatty acid. This finding is similar to the report of Ekunseitan et al. (2016) who reported high value of linoleic acid when mushroom flour was blend with wheat flour.

3.6 Free fatty acids and peroxide value of the flours during storage

Figure 1a and 1b show the free fatty acid and peroxide value of 100% maize and oyster mushroom flours and the blended samples stored at room temperature (25°C). At week zero, the free fatty acids (FFA) value of 100% maize flour was high compared to the 100% oyster mushroom flour (Figure 1a). The FFA values of the fortified flour samples decreased with an increase in the amount of oyster mushroom flour added to maize flour. Also, there was initially a rapid increase in the FFA value of the flours in the first six weeks of storage followed by a slight increase in the last six weeks of storage. The increase observed in the FFA value of the flour samples may be attributed to the

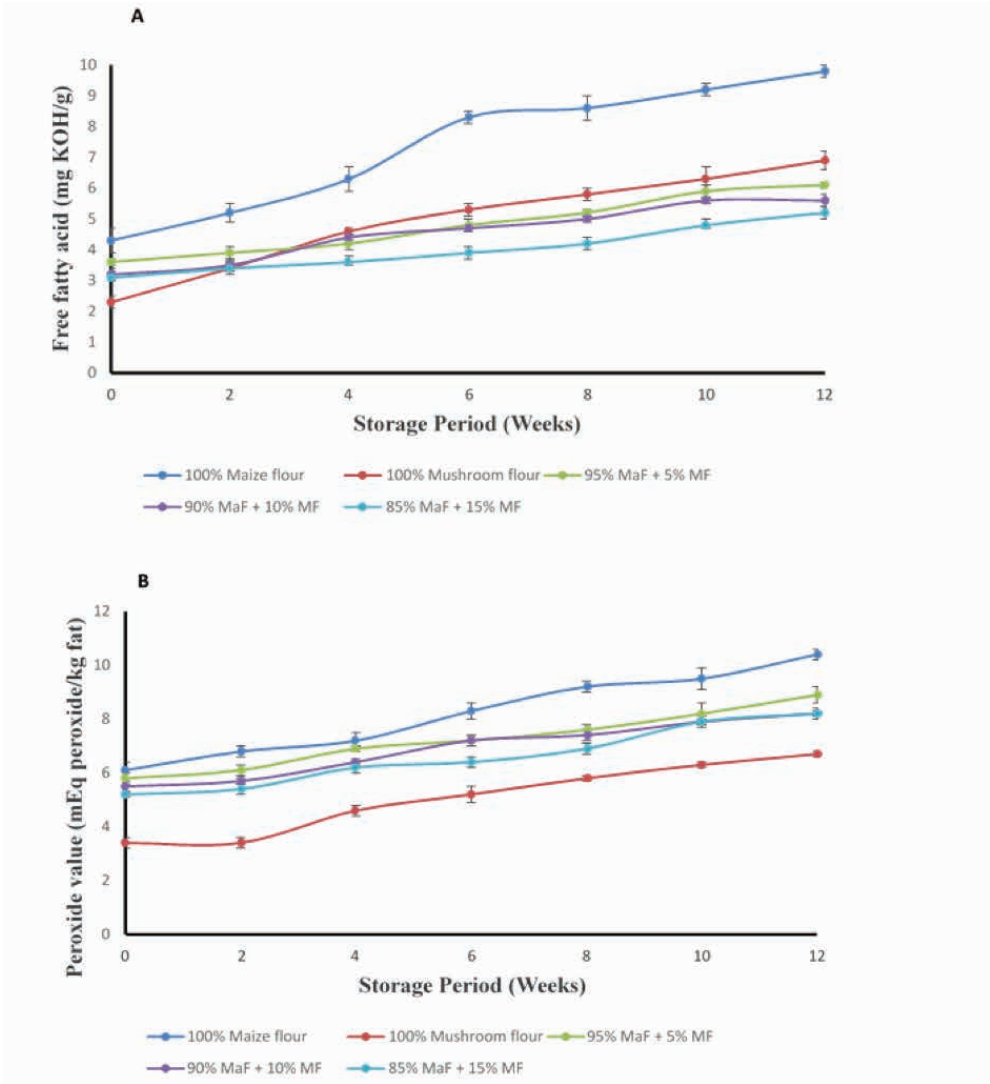


Figure 1: Free fatty acid of stored maize flour blends with mushroom flour and their control (A) Peroxide value of stored maize flour blends with mushroom flour and their control (B)

Keys: Controls are 100% maize flour and 100% mushroom flour; MaF is maize flour; MF is mushroom flour;

production of FFA by lipolysis due to the action of endogenous lipases that hydrolyzed the ester bond of acyl-glycerol (Min 2017). The slight increase in FFA value of the flour observed during the last six weeks of storage may be due to slight oxidation of the FFA or lipoxygenase-catalyzed peroxidation of polyunsaturated FFA. This finding is in line with the report of Hemery et al. (2018) who reported an increase in FFA value of stored non-fortified and fortified wheat flour. The addition of oyster mushroom flour to maize flour reduced the FFA values of the fortified flour thus making the blend samples more stable than 100% maize flour.

The peroxide value (PV) of the blends was lower compared to 100% maize and 100% oyster mushroom flour (Figure 1b). It was observed that the increase in the percentage of oyster mushroom flour in maize flour led to a slight decrease in PV. There was a rapid increase in PV values of all the flours for the first six weeks of storage while the last six weeks of storage showed a slight increase in PV values. The increase in PV values recorded for the first six weeks of storage may be attributed to oxidation of FFA, which led to the production of peroxide and subsequent increase in peroxide value. The slight increase of PV value observed for the last six weeks of the flour storage may be due to a reduction in the oxidation rate of FFA or degradation of the unstable compound into secondary oxidation products with the formation of a volatile compound, such as n-hexanal (Hayward et al. 2017).

4 Conclusions

This study demonstrates maize flour blends with oyster mushroom flour have higher nutritional and functional properties than maize flour alone. Also, the amino acids and fatty acids profile of the blend samples are similar to that of maize flour. The storage stability of the maize and oyster mushroom flour with their blends shows that the blend samples are relatively stable at room temperature for 3 months than maize flour alone with lower values of free fatty acid and peroxide. The composite flour containing 15% oyster mushroom flour with maize flour can serve as a nutrient enriched food source to address the problems of protein energy malnutrition and micronutrient deficiencies.

5 Recommendation

The purpose of compositing maize flour with oyster mushroom flour was to improve the nutritional quality of maize flour. This was achieved in this study. It may be recommended that an addition of 15% oyster mushroom in maize flour will increase the proximate composition of composite flour without a significant difference in the functional properties of the composited maize flour when compare to normal maize flour.

Acknowledgment: The authors will like to appreciate all scholar whose works were cited in this study.

Conflict of interest: The authors declared that there is no conflict of interest.

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