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# Nutritional and Functional Properties of Mushroom (*Agaricus bisporus* & *Pleurotus ostreatus*) and Their Blends with Maize Flour

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**Abstract** Protein-Energy Malnutrition (PEM) and micronutrient deficiencies are currently the most important nutritional problem in most countries. The use of mushroom flours is limited due to limited knowledge about their functional and their interactions. Nutritional and functional properties of mushroom (*Agaricus bisporus* and *Pleurotus ostreatus*) flours and their blends with maize flour were investigated using standard analytical techniques and Pearson correlations. In this study, maize flour was replaced with mushroom flours at different levels; a control sample (0%), 10%, 20%, 30%, 40% and 50% of mushroom flour. Protein content of maize flour increased with increased mushroom flour content from 6.9% to 15.87 % (*A. bisporus*) up to 19.32% (*P. ostreatus*). The mineral content increased from 2.84 – 8.74mg/100g and 3.13 – 5.41 mg/100g for iron and zinc in the composite flours. A significant increase in fiber (0.53-5.89%) and Ash (1.33-6.59%) was observed. Fat, moisture, carbohydrates and energy did not increase. It was observed a positive significant linear effect ($p \leqslant 0.05$) in the composite flours on foaming capacity, foam stability, fat absorption capacity, water retention capacity, water absorption capacity, solubility index and swelling capacity and a negative linear effect on compact density, bulk density and syneresis was found. Gelation capacity, emulsifying activity and emulsions stability of the maize flour in blend were not affected with adding *P. ostreatus*, while a slight decrease was observed with adding *A. bisporus*. These results suggested that these nutrient rich mushroom flours under investigation could serve as useful protein supplements and food fortification.

***Keywords:*** *food fortification, mushroom, maize flour, nutritional and functional properties*

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## 1. Introduction

Global problems that impact on health, economy and country development are malnutrition, food crisis and hunger [1]. A total of 925 million people in the world are still estimated to be undernourished, representing almost 16% of the population of developing countries [2]. It has been reported that 25% of world's population has a deficiency of protein intake in their diet. Nutritional inadequacy is a serious public health concern in low-income countries [3]. Young children, lactating and pregnant mothers are the most vulnerable groups.

Sub-Sahara Africa, especially Democratic Republic of Congo (D.R.C.) in particular continue to suffer from the twin problems of malnutrition and food insecurity [2]. Approximately 70% of the total population and more than 40% of children under the age of five are undernourished in D.R. Congo [4].

Poverty, inadequate food production and poor quality of food are some of the main contributors towards this huge burden [5]. Malnutrition exists in various forms, including acute and chronic under-nutrition, micronutrient deficiencies, as well as overweight and obesity [6]. Regarding anemia, 71% of children under five and 53% of women of reproductive age (19-49 years) are anemic [7].

The chronic form of this anemia results not only from iron deficiency but it is compounded by the effect of many infectious and parasitic diseases, including malaria and intestinal parasites especially in children. About anemia, a study conducted by UNICEF and PRONANUT showed that 82% of children are affected by anemia [8].

Protein-Energy Malnutrition (PEM) in young children is currently the most important nutritional problem in most countries, such as D.R. Congo [9]. Failure to grow adequately is the first and most important manifestation of PEM. It often results from consuming too little food, especially energy, and is frequently aggravated by infections.

The main challenge that consumers face in their daily menu is that the shortage of protein. Most of our cereal products and especially maize products are carbohydrate rich but less in protein 8.91-11.65% [10].

The most common cause of anaemia is a deficiency of iron, although not necessarily a dietary deficiency of total iron intake [11]. Iron deficiency is the most prevalent important nutritional problem of humans. It threatens over 60% of women and children in most non- industrialized countries, and more than half of these have overt anaemia [12]. Zinc is another essential nutrient and is apparently deficient in the diets of many people in both industrialized and non-industrialized countries. Low zinc status in children has been associated with retarded growth, poor appetite and impaired sense of taste [12].

Edible mushroom has been described as a rich source of protein, vitamins, fats, carbohydrates, minerals [13,14,15,16] and health-giving properties [17]. They are ranked to be richer than most food sources except meat in term of protein content [18].

Mushrooms have high and good protein content (20-40%) on dry weight basis [19]. Mushrooms can provide balancing diet compounds in sufficient quantities for human nutrition [20]. They also have high content of fibers and low cholesterol content [13,21].

Fortification of the maize flour using mushroom flour can improve the nutritional status of the flour. The use of mushroom flours is limited due to our lack of knowledge about their functional and compositional characteristics and their interactions.

Therefore, the present study aimed to investigate the nutritional quality and functional properties of two mushroom species (*Agaricus bisporus* and *Pleurotus ostreatus*) and maize flour with a view to provide vital information towards production of composite flours (maize-mushroom).

# 2. Methods

## 2.1. Sample Preparation

Two fresh mushroom species (*Pleurotus ostreatus*) oyster, (*Agaricus bisporus*) button and maize flour (*Zea mays*) were studied. Oyster and button were chosen on the basis of their being cultivated. Maize flour was chosen because maize meal is one of the staple food in most of African countries, especially in Republic Democratic of Congo.

The two mushroom species collected from Jomo Kenyatta University of Agriculture and Technology Enterprises (JKUATES) and maize flour purchased within Juja around JKUAT, were transported to Food Science Laboratory of JKUAT. The samples were turned regularly for almost one week until a moisture content of below 10% was attained. Then dried mushrooms were milled to mushroom flours which were used for different analysis. Maize flour was blended with mushroom flour at the following combinations: 0% (control), 10%, 20%, 30%, 40% and 50% of mushroom flour.

## 2.2. Nutritional Quality Determination

### 2.2.1. Proximate Composition

Moisture, protein, fat, fiber and ash content were determined in accordance with Official Methods [22]. Moisture and ash were determined by the hot-air circulating oven and through incineration in a muffle furnace respectively. Crude protein was determined by the micro-Kjeldahl method and its content was obtained by multiplying the corresponding total nitrogen content by a factor of 6.25 [23]. Available carbohydrate was determined by difference whereas energy was calculated using the Atwater's calorie conversion factors: 4 kcal/g for crude protein, 9 kcal/g for crude fat and 4 kcal/g for available carbohydrate [23].

### 2.2.2. Mineral Analysis

The iron and zinc content were determined according to the method of AOAC International [22].

## 2.3. Functional Properties Determination

### 2.3.1. Bulk Density

The bulk density was determined using the procedure of Okezie and Bello [24], with some modification by pouring 10g of flour into a 50mL measuring cylinder. The bulk density value was calculated as the ratio of mass of the powder and the volume occupied in the cylinder.

### 2.3.2. Compact Density

Compact density (CD) was measured according to the method reported by Due *et al*. [20]. 10g of the sample was weighed into a measuring cylinder. Then holding the cylinder on a vortex vibrator for 3 min to obtain a constant volume of the sample and the final volume (Vf) was measured.

$$\text{CD} = \text{Weight}\,(\text{g}) / \text{Vf}\,(\text{mL}).$$

### 2.3.3. Fat absorption Capacity

Fat absorption capacity (FAC) was assessed in triplicate using the procedure of Lin and Humbert [25]. A sample (0.3 g) was mixed with corn oil (3 mL) in a pre-weighed 10mL graduated centrifuged tube for 1 min. After centrifugation at 2060 rpm for 30 min, the supernatant was discarded and the tubes was re-weighed. The % FAC was expressed using the following equation:

$$\text{FAC}(\%) = \begin{bmatrix} \text{weight of sample} \\ +\text{oil} / \text{weight of sample} \end{bmatrix} {*}100.$$

### 2.3.4. Foaming Capacity and Foam Stability

They were assessed following the method as described by Yusuf et al. [26]. 2g of each sample was added to 50mL distilled water in a 100mL graduated cylinder. The suspension was then mixed and shaken for 5minutes to foam. The volume of foam at 30 seconds after whipping was expressed as foaming capacity (FC) using the following formula:

$$\text{FC}\% = \frac{\text{V2}(\text{mL}) - \text{V1}(\text{mL})}{\text{V1}(\text{mL})} \text{X100}$$

Where:

V1 is the original volume of sample (mL) and V2 volume of foam after whipping.

The volume of foam (V3) was recorded one hour after whipping to determine the foaming stability (FS) as a percentage of the initial foam volume.

$$FS\% = \frac{V3(mL) - V1(mL)}{V1(mL)} X100.$$

#### 2.3.5. Emulsifying Activity and Stability of the Emulsion

Emulsifying activity (EA) of flours was determined using the procedure as described by Neto *et al.* [27]. 1g was dispersed in 10 mL distilled water and the height of solution in the cylinder was measured. After homogenization with refined canola oil (5mL), the resulting emulsion was centrifuged for 5 minutes at 1100xg. The height of the emulsified layer was measured and the emulsifying activity was calculated as the percent increase in the height of the solution by the following equation:

$$EA(\%) = \frac{H2(mL)}{H1(mL)} X100$$

Where, H1 is the initial height of the solution before emulsification and H2 is the height of the emulsified layer.

To evaluate stability of the formed emulsion, the samples were subjected to temperature cycles of 85±3°C for 15 min in the water bath and later left at an ambient temperature of 27°C for 30min. The height of the emulsified layer was then recorded (H3) and the stability of the emulsion (SEC) was calculated using the following formula:

$$SEC(\%) = \frac{H3(mL)}{H1(mL)} X100.$$

#### 2.3.6. Least Gelation Concentration

Mushroom and maize powder sample suspensions of 2-20% were prepared in distilled water and vortexed for 5minutes. 10mL of each prepared dispersion was transferred into a test tube. The tubes were heated at 90°C for 30 minutes in water bath and then placed in a cold room at 4°C for 30minutes. The gelation concentration was determined as the lowest concentration at which the sample does not fall down or slip from an inverted test tube [28]. The gels were characterized as absence of gel (-), mobile gel (±), firm gel (+) and very firm gel (++).

#### 2.3.7. Syneresis

Syneresis (SYN) was measured applying the method of Banerjee and Bhattacharya [29]. A suspension of 14% (w/v) in 5mL of warm water for each sample was prepared in centrifuge tubes. Agitation was applied until a mixture without lumps was obtained. The mixture was weighed and the initial weight was recorded (weight 1). This dispersion was cooled at room temperature, and then covered and stored at 8oC for 48h. Afterwards, the mixture was centrifuged at 1650 r/min for 15 min, the supernatant was removed and the final weight was recorded (weight 2). SYN% was calculated as follows:

$$SYN\% = \frac{Weight1(g) - Weight2(g)}{Weight1(g)} X100.$$

#### 2.3.8. Swelling Capacity

Swelling capacity (SC) was determined following the method of Tosh and Yada [30]. 2.5 g of the sample was measured in a 50mL measuring cylinder; excess water (30 mL) was added and mixed until homogeneity is reached. The mixture was then left to settle for 24h, and the final volume (Vf) occupied by the sample was measured. The SC will be obtained as follows:

$$SC = \frac{Vf(mL)}{Sample\ weight(g)}.$$

#### 2.3.9. Water Absorption Capacity

Water Absorption Capacity (WAC) is expressed as the maximum quantity of water that can be absorbed in the presence of an excess of water, with a hydration time of less than 1h and after being subjected to an external force. WAC was determined following the methodology of Wang and Toews [31]. 0.5g of sample was weighed in a test tube and an excess of water (10mL) was added. The mixture was agitated and left to hydrate for 30min. After centrifugation at 1650 r/min for 10 minutes the mixture was left to settle and to separate the supernatant. Finally, the sediment was weighed. The WAC was calculated as follows:

$$WAC = \frac{Sediment\ weight(g) - sample\ weight(g)}{Sample\ weight(g)}.$$

#### 2.3.10. Water Retention Capacity and water Solubility Index (SOL%)

Water retention capacity (WRC) is the quantity of water retained under conditions of hydration for prolonged periods and subjected to an external force. Water solubility index (SOL %) is expressed as the percentage of the soluble fraction of the sample in the presence of excess water, and it is calculated indirectly. They were determined using the method of Kaur and Singh [32]. 1 g of the sample was weighed and 30 mL of distilled water was added. The mixture was shaken and left to hydrate for 24h. Subsequently, the mixture was centrifuged at 2000 r/min for 30 min. The supernatant was then separated and the hydrated sediment was weighed. Afterwards, the sediment was transferred to a moisture dish and dried at 105°C for 6h, and then the dry sediment was weighed. The WRC was calculated as follows:

$$WRC = \frac{\begin{bmatrix} Hydrated\ sediment\ weight(g) \\ -Dry\ sediment\ weight(g) \end{bmatrix}}{Dry\ sediment\ weight(g)}$$

$$SOL\% = \frac{Sample\ weight(g) - Dry\ sediment\ weight(g)}{Dry\ sediment\ weight(g)}.$$

### 2.4. Data Analysis

All samples were statistically analyzed at least in triplicates and data presented as mean ± standard deviation (n≥3). The means were subjected to a one-way ANOVA for significance test (p≤0.05) using GenStat version 14 and Statistix 8.0.

## 3. Results and Discussion

### 3.1. Nutritional Quality of Composite Flours

Table 1 presents the nutritional composition of two edible mushrooms, maize flours and their blends. The percentage moisture content in composite flours ranged from 9.86-11.12%, whereas that for maize flour was 11.69%. The moisture content found in composite flour is similar to the value of corn (10.16%) reported by Lopera-Cardona et al. [33].

The percentage of total proteins gives additional nutritional value to whole meal flour. The oyster mushroom flour stood out in terms of its protein content, with a value greater than 31.69%, followed by button flour 24.79% and 6.95% of protein content in maize flour. Comparable results have been found previously in the thick bodies of edible mushrooms, reporting glycoprotein contents of between 20 and 40% on dry weight basis [15,33,34].

The results of different mixtures in Figure 1 show that increasing in mushroom content for both oyster and button mushrooms resulted in increasing of the protein content for the different blends. Maize + 40% to 50 % oyster and maize + 50% button showed significantly ($p \leq 0.05$) higher protein content than control sample and other composite flours. Similar results were obtained by Okafor et al. [35], with replacement of wheat flour by mushroom powder, which resulted into increasing the protein content of the bread. Farzana *et al.* [36] also observed an increase in vegetable soup powder supplemented with mushroom. Similarly, Ekunseitan *et al.* [37] reported that adding mushroom flour to cassava and wheat flours increases the protein levels.

The iron content (Fe) increased from 2.84 (maize flour) to 8.73mg/100g in composite flours fortified with 50% button flour. The samples differed significantly ($p \leq 0.05$). The iron in this study corresponds to the Recommended Daily Allowance (RDA) of iron 15mg/day for females 14-18 years and 11mg/day for males 14-18 years [38]. The Iron content increased with increasing mushroom flour content and ranged within 13.65 to 14.75mg/100g in the mushroom species. Kalagbor and Diri [39] reported that the Iron is important in haemoglobin formation, oxygen and electron transport in the human body.

Normal birth weight infants whose mothers had good prenatal iron status usually have adequate liver iron reserves, and thus the risk of iron deficiency before six months is low [40]. The Iron content in this study is less than the maximum limit of iron concentration in food given by FAO/WHO [41] which is 42.5 mg/100g. Infants of mothers with prenatal iron deficiency may also be at risk, even if their birth weight is normal [40].

The values for zinc density increased from 3.13mg/100g to 5.41mg/100g in the complementary foods. Increasing mushroom content resulted in increasing the zinc content for both mushroom species. Low liver reserves of zinc at birth may predispose some infants to zinc deficiency [42], similar to the situation for iron [40]. There was significant difference ($p \leq 0.05$) in the zinc density for the fortified maize flour compare to the control. However, it can be concluded from the results that the composite flours can contribute significant amount of zinc to the infant and women especially pregnant women.

Results indicated that the crude fiber of mushrooms was considerably higher than that of maize. The substitution of maize flour with mushroom flours resulted to increase in the fiber content for all blends. It increased from 0.53% in maize flour to 3.25% composite flour. These values are comparable with most legumes such as pigeon pea and cowpea, *Phaseolus coccineous* L. [43]. There is evidence that dietary fiber has a number of beneficial effects related to its indigestibility in the small intestine.

A total fat content of less than 6% was quantified in all flours. There was no significant difference between maize and button flours in the fat concentration, indicating that it's possible to include button flour into maize flour without affecting the nutritional fat of the maize flour. However, increasing oyster flour content resulted into a decrease in fat content of maize flour. The Ash content in all the flour and blends studied was less than 13%.

High content of carbohydrates (from 42 to 74%) indirectly determined in all flours, followed the order: oyster<button<maize. A strong negative correlation ($r = -0.971$) was observed between the protein and carbohydrates content in Table 3.

**Table 1. Nutritional density of the different composite flours**

| CF | MC% | Fiber% | Fat % | Protein % | CHO % | Ash % | Energy (Kcal) | Fe (mg/100g) | Zn (mg/100g) |
|---|---|---|---|---|---|---|---|---|---|
| MF | $11.69^{a}\pm0.08$ | $0.53^{a}\pm0.02$ | $5.83^{a}\pm0.58$ | $6.95^{h}\pm0.42$ | $73.67^{a}\pm0.78$ | $1.33^{i}\pm0.02$ | $374.9^{a}\pm3.08$ | $2.84^{j}\pm0.08$ | $3.13^{g}\pm0.06$ |
| BF | $7.82^{g}\pm0.19$ | $5.63^{ab}\pm3.14$ | $5.26^{ab}\pm0.8$ | $24.79^{b}\pm0.61$ | $43.51^{g}\pm3.42$ | $12.99^{a}\pm0.25$ | $320.5^{g}\pm14.71$ | $14.75^{a}\pm0.62$ | $6.32^{a}\pm0.13$ |
| OF | $9.12^{f}\pm0.17$ | $6.34^{d}\pm2.02$ | $2^{f}\pm0.34$ | $31.69^{a}\pm0.79$ | $42.3^{g}\pm2.56$ | $8.56^{b}\pm0.21$ | $313.9^{g}\pm6.01$ | $13.65^{b}\pm1.3$ | $6.51^{a}\pm0.19$ |
| B10% | $11.12^{ab}\pm0.18$ | $0.99^{d}\pm0.09$ | $5.6^{a}\pm2.2$ | $8.73^{h}\pm0.53$ | $71.06^{ab}\pm0.43$ | $2.5^{g}\pm0.04$ | $369.56^{ab}\pm1.76$ | $5.29^{hi}\pm0.23$ | $3.86^{f}\pm0.24$ |
| B20% | $10.35^{bc}\pm0.23$ | $1.45^{cd}\pm0.03$ | $5.48^{ab}\pm0.22$ | $10.51^{g}\pm0.18$ | $68.59^{bc}\pm0.92$ | $3.62^{f}\pm0.01$ | $365.72^{a}\pm8.07$ | $6.63^{efg}\pm0.27$ | $3.92^{f}\pm0.23$ |
| B30% | $10.8^{bcd}\pm0.25$ | $2.03^{cd}\pm0.43$ | $5.39^{ab}\pm0.14$ | $12.3^{g}\pm0.17$ | $64.88^{d}\pm2.99$ | $4.6^{e}\pm0.05$ | $357.23^{c}\pm18.19$ | $6.84^{ef}\pm0.23$ | $4.22^{ef}\pm0.33$ |
| B40% | $10.04^{bc}\pm0.8$ | $2.54^{cd}\pm0.09$ | $5.35^{ab}\pm0.29$ | $14.09^{f}\pm0.44$ | $62.09^{e}\pm0.78$ | $5.89^{d}\pm0.06$ | $352.87^{ef}\pm7.06$ | $7.85^{cd}\pm0.09$ | $4.7^{cd}\pm0.01$ |
| B50% | $9.86^{e}\pm0.35$ | $2.89^{ab}\pm0.35$ | $5.30^{ab}\pm0.84$ | $15.87^{e}\pm0.53$ | $59.49^{ef}\pm1.84$ | $6.59^{c}\pm0.26$ | $349.14^{f}\pm12.69$ | $8.73^{c}\pm0.94$ | $5.07^{bc}\pm0.42$ |
| O10% | $10.9^{bcd}\pm0.27$ | $1.04^{cd}\pm0.53$ | $4.17^{bc}\pm0.47$ | $9.42^{g}\pm0.35$ | $72.64^{bc}\pm1.98$ | $1.83^{h}\pm0.14$ | $365.77^{a}\pm11.33$ | $4.78^{i}\pm0.25$ | $4.51^{de}\pm0.25$ |
| O20% | $10.76^{bcd}\pm0.15$ | $1.65^{cd}\pm0.34$ | $3.32^{cd}\pm0.69$ | $11.89^{f}\pm0.27$ | $69.78^{cd}\pm0.86$ | $2.59^{g}\pm0.02$ | $356.6^{ab}\pm4.09$ | $5.85^{gh}\pm0.47$ | $4.73^{cd}\pm0.2$ |
| O30% | $10.57^{cd}\pm0.23$ | $2.08^{cd}\pm0.73$ | $2.97^{de}\pm0.24$ | $14.37^{e}\pm0.29$ | $66.34^{d}\pm0.66$ | $3.66^{f}\pm0.63$ | $349.61^{bc}\pm3.16$ | $6.52^{fg}\pm0.06$ | $5.06^{bc}\pm0.29$ |
| O40% | $10.43^{d}\pm0.1$ | $2.77^{cd}\pm0.68$ | $2.77^{ef}\pm0.29$ | $16.85^{d}\pm0.63$ | $63.14^{de}\pm0.67$ | $4.04^{f}\pm0.04$ | $344.89^{bc}\pm4.29$ | $7.07^{def}\pm0.7$ | $5.18^{b}\pm0.22$ |
| O50% | $10.44^{d}\pm0.25$ | $3.25^{bc}\pm0.63$ | $2.11^{f}\pm0.84$ | $19.32^{c}\pm0.27$ | $59.99^{f}\pm2.26$ | $4.89^{d}\pm0.74$ | $336.23^{de}\pm1.76$ | $7.51^{de}\pm0.21$ | $5.41^{b}\pm0.06$ |

Mean values (n=3) ±sd on dry weight basis. Values in the same column with the same following letter do not significantly differ ($p<0.05$).
CF: Composite flours; MF: Maize flour; BF: Button four; B10%: Button 10%+90% MF; B20%: Button 20%; B30%: Button 30%; B40%: Button40%; B50%: Button 50%; O10%: Oyster10%; O20%: Oyster 20%; O30%: Oyster 30%; O40%: Oyster 40%; O50%: Oyster 50%; MC: Moisture content & CHO: carbohydrates.

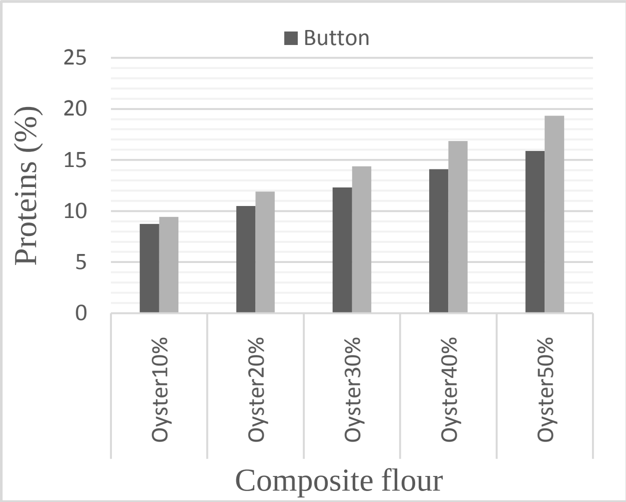


**Figure 1.** Effect of blending on protein content in composite flours

## 3.2. Functional Properties of Composite Flours

The functional properties of different flours and blends were summarized in Table 2. Results show a positive significant linear effect (p≤0.05) in the composite flours on foaming capacity (FC), foam stability (FS), fat absorption capacity (FAC), water retention capacity (WRC), water absorption capacity (WAC), solubility index (SOL) and swelling capacity (SC) and a negative linear effect on compact density (CD), bulk density (BD) and syneresis was found.

The BD of the studied flours was found to be 0.6 g/mL in maize flours. While in composite flours it ranged from 0.35 to 0.5 g/mL. These values are close to those of mushroom flours reported by Aremu *et al.* [44], suggesting that it would serve as good thickeners in food products. However, CD values (Table 2) show that addition of both mushroom flours decreases the CD of maize flour. The accumulation of minerals due to chelation and the presence of acids in fibrous and porous materials could explain this [45]. Flours with compact particles, poor porosity and high contents of starch, give values of CD close to 0.6 g/mL [46]. This could explain why the CD of maize flour in this study was found to be 0.87g/mL.

The fat absorption capacity (FAC) varied from 297.3% in maize flour, 462.6% in oyster flour to 548.3% in button flour. These values were found to be comparable to those reported [44] for flours from *Ganoderma spp*., *O. olearius* and *H. mesophaeum*, ranging from 450-480 %. FAC is exhibited by the proteins in the flour which physically bind to fat by capillary attraction. FAC play a significant role in ground meat formulations like sausages and to increase the shelf life of meat products [47].

The properties of SC, SOL, WAC and WRC increased with increasing mushroom flours content. This could explain by the dependent on the hydrophilic constituents of the material such as polysaccharides and proteins, which are related with diffusion phenomena and affinity for water. Our results were consistent with the results previous work, 10.38mL/g in corn and 12.24mL/g in oyster mushroom of SC and a SOL% of 11.36% and 53.81% respectively in corn and oyster mushroom [33]. These properties were relevant probably because the presence of fibers and the porous morphology favoured absorption, retention and swelling of flour particles in water.

Syneresis is an undesirable phenomenon in gels. Low syneresis values in gel systems are considered to be between 1.5 and 2% [29]. In Table 2, the results of the syneresis evaluation of the studied materials are presented with a significant variation (p≤0.05). Adding mushroom flours resulted into decreasing syneresis value.

WAC, WRC and SOL% hydration variables significantly (p≤0.05) correlated with CD in Table 3. A negative and high correlation is obtained (r=-0.733, r=- 0.734 and r=-0.652) in good accordance with the dependence of density on morphological aspects of the material like porosity and fiber structure, which is characteristic of whole meal flour [48].

Results on foaming capacity, foam stability, emulsion activity and emulsion stability (Figure 2a) exhibited significant (p≤0.05) depending on the type of flour. Emulsifying activity and emulsions stability of the maize flour in blend (Figure 2b) were not affected with adding *P. ostreatus*, while a slight decrease in EA and ES was observed with adding *A. bisporus*. All materials evaluated showed emulsifying properties ranged from 34.23% to 49.74%, results being consistent with their carbohydrate and protein contents (Table 1). The emulsifying properties of a material are associated with the presence of agents that can form and stabilize emulsions due to changes in surface activity, electrostatic repulsion or entropic repulsion.

EA is the maximum amount of oil emulsified by protein in the given amount of flour. The EA values of maize and mushroom flours were found to be higher than those reported for maize flour [49] and mushroom flour [50]. The comparatively higher EA of different flours and their blends makes them better to be used in food formulations. Emulsion characteristics of flours and proteins contribute much to their functionality in foods [51]. Our results on EA and ES suggest that the different flours and their blends would be desirable for preparing ground meat formulations such as sausages, baked foods, mayonnaise and soups.

The foam capacity (FC) and stability (FS) increased from 5.51 to 46.3% and from 1.85 to 27.48% respectively in composite flour compare to maize flour. Figure 2 information shows the foaming properties of the different flours and their blends. The FC and FS of the button flour were significantly (p≤0.05) higher than those of oyster and maize flours. A positive correlation (r= 0.99) between the FC and FS was also observed (Table 3). The foaming capacity of the button is comparable close to the value reported in other mushroom varieties, *Omphalotus olearius* (101.8%) and lower to 131.48 % found in *Hebeloma mesophaeum* [52].

The flour from oyster shows foaming capacity of 18.86% which is higher than values of pearl millet flour (11.30%) reported by Oshodi *et al.* [53]. However, this value is lower than those reported for *Pleurotus* mushrooms [54] ranging from 32 to 64% and mushroom flours from Nigeria about (50%) as reported by Aremu et al. [44]. This suggests that the mushroom samples studied may be attractive for products like cakes or whipping topping where foaming is important [55]. FC and FS are indices of whippability, hence, the high values recorded in this study showed that *P. ostreatus*, *A. bisporus* and their blends seem suitable for food products that require a high percentage of porosity.

The least gelation concentration is the ability of flour to form gel which provide structural matrix for holding water and other water-soluble materials like sugars and flavors. The lower the level of the LGC, the better the gelation capacity of the protein ingredient [56]. In this present study, the gelation capacity of the composite flours was not affected by adding oyster flour, whereas a slight decrease in gelation capacity was observed with increasing button flour content. LGC ranged from 8% in *Zea mays* and *Pleurotus ostreatus* to 12% in *Agaricus bisporus*. Variation in the values obtained might be linked to the relative ratio of different constituents such as protein, carbohydrates and lipids as suggested by Sathe et al. [57] that the interaction between such components may affect functional properties.

LGC of *P. ostreatus* and *Zea mays* flours were found to be comparatively higher than that reported, 5.7% for *P. ostreatus* [33], and 4% for *Zea mays* [49]. The value recorded for *A. bisporus* (12%) is comparable to *Omphalotus olearius* (12%), *Hebeloma mesophaeum* (12%) and to 14.0% in *Ganoderma spp*, 14%, as reported by Lethbridge [52].

The gelation property of the flour provides consistency in food preparations especially the semi-solid products [58]. This gives rise to the coexistence of diverse types of intermolecular relationships, such as hydrogen bridges, disulphide bonds and hydrophobic interactions, until a tridimensional network is exhibited [59]. The low gelation concentration of the different flours and their blends in this study suggests that they are suitable for food systems that require thickening and gelling.

**Table 2. Functional properties of composite flours**

| Flours | BD(g/mL) | CD(g/mL) | FAC% | SC(mL/g) | SOL% | SYN% | WAC(g/g) | WRC(g/g) |
|---|---|---|---|---|---|---|---|---|
| T1 | $0.6^{a}\pm0.02$ | $0.87^{a}\pm0.03$ | $297.2^{d}\pm30.73$ | $12.81^{c}\pm0.06$ | $18.64^{g}\pm5.66$ | $19.85^{a}\pm2.71$ | $2.56^{gh}\pm0.13$ | $1.85^{e}\pm0.18$ |
| T2 | $0.22^{i}\pm0.00$ | $0.31^{g}\pm0.01$ | $548.3^{a}\pm33.46$ | $14.47^{a}\pm0.2$ | $60.25^{ab}\pm7.3$ | $5.93^{f}\pm0.73$ | $5.43^{b}\pm1.06$ | $11.9^{a}\pm3.02$ |
| T3 | $0.28^{h}\pm0.01$ | $0.36^{g}\pm0.01$ | $462.6^{ab}\pm109.05$ | $13.71^{ab}\pm0.28$ | $50.99^{bcde}\pm6.66$ | $9.41^{e}\pm3.61$ | $7.19^{a}\pm0.44$ | $6.27^{bc}\pm0.36$ |
| T4 | $0.5^{c}\pm0.00$ | $0.76^{b}\pm0.04$ | $302.2^{d}\pm27.19$ | $12.3^{c}\pm0.51$ | $24.95^{fg}\pm3.64$ | $17.55^{ab}\pm0.71$ | $2.72^{h}\pm0.01$ | $2.53^{de}\pm0.23$ |
| T5 | $0.44^{e}\pm0.00$ | $0.64^{cd}\pm0.01$ | $366.6^{bcd}\pm56.92$ | $12.38^{c}\pm0.35$ | $31.56^{f}\pm0.93$ | $15.23^{bc}\pm2.13$ | $3.05^{fgh}\pm0.44$ | $3.71^{cde}\pm0.43$ |
| T6 | $0.38^{f}\pm0.03$ | $0.66^{cd}\pm0.12$ | $378.8^{bcd}\pm31.23$ | $12.55^{c}\pm0.57$ | $35.53^{e}\pm2.43$ | $14.15^{cd}\pm0.73$ | $3.51^{ef}\pm0.89$ | $4.29^{cde}\pm0.14$ |
| T7 | $0.39^{f}\pm0.01$ | $0.55^{ef}\pm0.01$ | $379.6^{bcd}\pm11.17$ | $12.62^{c}\pm0.47$ | $38.38^{abc}\pm5.97$ | $13.34^{cd}\pm1.58$ | $4.11^{de}\pm0.24$ | $5.83^{bcd}\pm0.61$ |
| T8 | $0.35^{g}\pm0.01$ | $0.49^{f}\pm0.01$ | $433.2^{bc}\pm26.03$ | $12.97^{bc}\pm0.32$ | $44.47^{a}\pm3.76$ | $11.87^{de}\pm2.31$ | $4.39^{d}\pm0.53$ | $8.33^{ab}\pm1.7$ |
| T9 | $0.53^{b}\pm0.02$ | $0.77^{b}\pm0.02$ | $314.1^{bcd}\pm31.61$ | $12.28^{c}\pm0.48$ | $21.6^{f}\pm8.07$ | $19.06^{a}\pm0.88$ | $3.27^{fg}\pm0.33$ | $2.08^{de}\pm1.11$ |
| T10 | $0.48^{d}\pm0.00$ | $0.69^{c}\pm0.02$ | $333.7^{cd}\pm86.78$ | $12.35^{c}\pm0.62$ | $28.21^{e}\pm7.88$ | $18.16^{ab}\pm1.38$ | $3.43^{ef}\pm0.13$ | $3.25^{cde}\pm0.3$ |
| T11 | $0.43^{e}\pm0.01$ | $0.61^{de}\pm0.01$ | $374.1^{bcd}\pm20.93$ | $12.42^{c}\pm0.73$ | $33.5^{cde}\pm5.54$ | $15.44^{bc}\pm0.96$ | $3.96^{de}\pm0.76$ | $4.04^{cde}\pm0.26$ |
| T12 | $0.38^{f}\pm0.01$ | $0.55^{f}\pm0.01$ | $389.9^{cd}\pm129.55$ | $12.48^{bc}\pm1.02$ | $35.59^{de}\pm1.96$ | $13.93^{cd}\pm1.05$ | $4.46^{d}\pm0.19$ | $4.44^{cde}\pm1.11$ |
| T13 | $0.35^{g}\pm0.01$ | $0.5^{f}\pm0.01$ | $400.4^{bc}\pm54.54$ | $12.57^{c}\pm0.5$ | $41.82^{abcd}\pm11.15$ | $13.22^{cd}\pm1.49$ | $5.27^{bc}\pm0.46$ | $5.25^{bcd}\pm0.39$ |

Mean values (n=3) ±sd. Values in the same column with the same following letter do not significantly differ ($p<0.05$).
BD: Bulk density; CD: compact density; FAT: fat absorption capacity; SC: swelling capacity; SOL%: solubility index; WAC: water absorption capacity; WRC: water retention capacity; SYN%: syneresis. T1: maize flour; T2: button flour; T3: oyster flour; T4: 10%button; T5: 20%button; T6: 30%button; T7: 40%button; T8: 50%button; T9: 10%oyster; T10%: 20%oyster; T11: 30%oyster; T12: 40%oyster & T13:50%oyster.

**Table 3. Coefficients of the Pearson correlations between nutritional and functional properties of composite flours**

| | MC% | Fiber% | Fat % | Protein % | CHO % | Ash % |
|---|---|---|---|---|---|---|
| Fiber% | **-0.764** | | | | | |
| Fat % | 0.456 | -0.507 | | | | |
| Protein % | **-0.871** | 0.678 | 0.526 | | | |
| CHO % | **0.929** | **-0.802** | 0.472 | **-0.971** | | |
| Ash % | **-0.914** | **0.835** | -0.459 | **0.806** | **-0.904** | |
| Energy (Kcal) | **0.815** | **0.891** | 0.575 | **-0.768** | **0.837** | **-0.896** |

| | BD(g/mL) | CD(g/mL) | FAC% | FC% | FS% | EA% | ES% | SC(mL/g) | SOL% | Syneresis | WAC(g/g) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CD(g/mL) | 0.284 | | | | | | | | | | |
| FAC% | -0.275 | **-0.804** | | | | | | | | | |
| FC% | -0.327 | -0.546 | **0.786** | | | | | | | | |
| FS% | -0.299 | -0.474 | **0.748** | **0.99** | | | | | | | |
| EA% | -0.186 | 0.319 | -0.384 | -0.549 | -0.478 | | | | | | |
| ES% | -0.127 | 0.179 | -0.038 | -0.055 | 0.018 | 0.462 | | | | | |
| SC(mL/g) | 0.053 | -0.354 | 0.399 | 0.36 | 0.272 | -0.634 | -0.143 | | | | |
| SOL% | -0.608 | -0.652 | 0.671 | 0.546 | 0.525 | 0.103 | -0.185 | -0.048 | | | |
| Syneresis | 0.525 | **0.754** | **-0.814** | -0.668 | -0.596 | 0.339 | 0.342 | -0.384 | **-0.832** | | |
| WAC(g/g) | -0.326 | **-0.733** | **0.691** | 0.305 | 0.241 | -0.1 | -0.198 | 0.303 | 0.659 | **-0.831** | |
| WRC(g/g) | -0.463 | **-0.734** | **0.816** | **0.886** | **0.843** | -0.428 | -0.276 | 0.359 | **0.797** | **-0.882** | 0.563 |

MC: Moisture content; BD: Bulk density; CD: compact density; FAT: fat absorption capacity; FC: foam capacity; FS: foam stability; EA: emulsification activity; ES: Emulsion stability; SC: swelling capacity; SOL%: solubility index; WAC: water absorption capacity; WRC: water retention capacity; SYN%: syneresis.

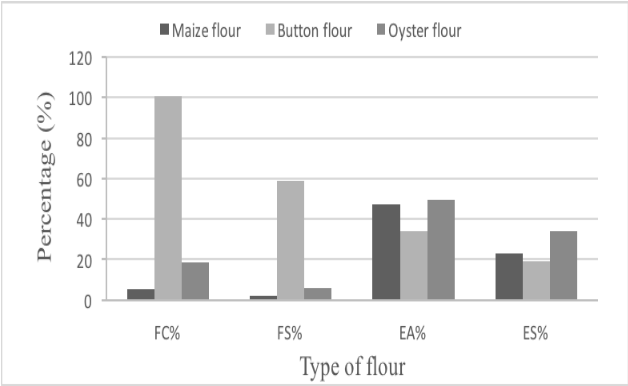


**Figure 2a.** Emulsifying activity and foaming capacity of Maize, Button and Oyster flours. Mean values (n=3)±sd. Emulsifying activity (EA%), stability of the emulsion (SE%), foaming capacity (FC%) and foam stability (FS%).

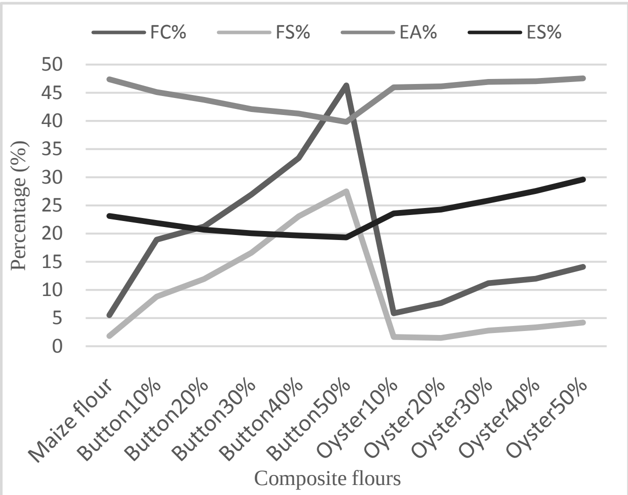


**Figure 2b.** Effect of blending on emulsifying activity and foaming capacity in composite flours

**Table 4. Least gelation for flour material**

| Flours | Percentage (g sample/100g $H_2O$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 12 | 14 | 16 | 18 | 20 |
| Maize | - | - | - | ± | ± | + | + | + | ++ |
| Button | - | - | - | - | ± | ± | ± | + | + |
| Oyster | - | - | - | ± | ± | ± | + | ++ | ++ |
| Button10% | - | - | - | ± | ± | ± | + | + | ++ |
| Button20% | - | - | - | ± | ± | ± | + | + | ++ |
| Button30% | - | - | - | - | ± | ± | + | + | ++ |
| Button40% | - | - | - | - | ± | ± | + | + | + |
| Button50% | - | - | - | - | ± | ± | ± | + | + |
| Oyster10% | - | - | - | ± | ± | + | + | + | ++ |
| Oyster20% | - | - | - | ± | ± | ± | + | ++ | ++ |
| Oyster30% | - | - | - | ± | ± | ± | + | ++ | ++ |
| Oyster40% | - | - | - | ± | ± | ± | + | ++ | ++ |
| Oyster50% | - | - | - | ± | ± | ± | + | ++ | ++ |

Type of gel: - Absence of gel, ± mobile gel, + Firm gel, ++ Very firm gel.

# 4. Conclusion

The results of this work showed significant ($p \leq 0.05$) diversity in the proximate and functional properties. Our study showed that protein, iron, zinc and fiber content of the composite flours increased with the increase in mushroom flours indicating that they can be used in human diet to prevent undernourishment due to protein and micronutrient deficiency. Contrarily, they were found to be low-fat foodstuffs.

Increasing mushroom flour content resulted into an increase in the composite flours on foaming capacity, foam stability, fat absorption capacity, water retention capacity, water absorption capacity, solubility index and swelling capacity and a decrease on compact density, bulk density and syneresis. Gelation capacity, emulsifying activity and emulsions stability of the maize flour in blend were not affected with adding *P. ostreatus*, while a slight decrease was observed with adding *A. bisporus*. The Protein Energy Malnutrition (PEM) and micronutrient deficiency of the population can therefore be reduced through the development of maize-mushroom composite flours.

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