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Nutritional and Physical Attributes of Maize-mushroom Complementary Porridges as Influenced by Mushroom Species and Ratio

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Abstract Child malnutrition is common in developing countries. one of the major contributing factor of the wide-spread problems of malnutrition among infants and children is the use of cereal-based foods, including maize meal porridge that are characterized by low protein content and micronutrients deficiency. This calls for action to develop home based enrichment of traditional foods by exploiting the nutritious foods like mushrooms that are rich in protein and micronutrients content. Nutritional and physical attributes of the maize meal porridges fortified with mushroom (*Agaricus bisporus* and *Pleurotus ostreatus*) flours were investigated. The maize flour was replaced with mushroom flours at different levels; a control sample (0%), 10%, 20%, 30%, 40% and 50% of mushroom flour. Increasing both *A. bisporus* and *P. ostreatus* flour content resulted in increasing of protein, in vitro-protein digestibility, micronutrients (zinc and iron) and fiber. Furthermore, increasing mushroom content resulted in decreasing of fat, carbohydrates, energy and viscosity. However, adding *P. ostreatus* flour resulted in increasing of the pH and decreasing of the Total titratable acidity (TTA). On the other hand, increasing the *A. bisporus* flour resulted in decreasing of the pH and increasing of the TTA. A strong significant ($p<0.05$) linear correlation (-0.73) was observed between the in vitro-protein digestibility and the viscosity in maize-mushroom porridges. Considering the protein content, micronutrients content, the in vitro-protein digestibility and the decreased viscosity, these fortified porridges can highly contribute to reduce the protein malnutrition and micronutrients deficiency.

Keywords: *fortified porridges, mushroom, maize porridge, nutritional and physical attributes*

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1. Introduction

Child malnutrition is common in developing countries [1,2], and affects their morbidity, mortality, cognitive development, reproduction and physical work capacity [3,4,5]. Furthermore, growth faltering is affecting as many as 33% of all children under 5 years of age [6]. However, one of the major contributing factor of the wide-spread problems of malnutrition among infants and children is the use of cereal-based foods that are characterized by low protein content [7,8], energy and micronutrients deficiency [8,9,10] that they are fed during the weaning period [11]. In addition to these nutritional problems, the rapid increase in urbanization in Africa has led to the need for convenience type meals prepared from easily available foods [12].

Deficiency of energy and essential nutrients during the complementary feeding period (the age range of 6-24 months) can have serious consequences on the health and wellbeing of infants at a later age in life, some of which are long lasting/irreversible [13]. The issue is even worse during the second six months of life [14], coupled with high rates of infections during the first two years of life [15]. Women and children are more vulnerable to nutritional deficiencies than other members of the community. Nearly half (45%) of all childhood deaths can be linked to undernutrition [16,17].

Stunting is a major development problem in the Democratic Republic of Congo (D.R. Congo), with about 70% of the total population and more than 40% of children under the age of 5 are undernourished [4,18]. Based on the body mass Index (BMI) assessments, 47% of the overall adults are underweight, and 1% are overweight [19]. According to the Global Hunger Index, the country is ranked the highest in sub-Sahara Africa [20]. Some of the main contributors towards this huge burden are poverty, inadequate food production and poor quality of food [4], due to political unrest, lack of proper management, heavy corruption and stagnant economy. Despite the fact that the country is endowed with large arable land, and abundant natural resources [4].

Anemia is a serious health problem in the D.R. Congo [21]. The Demographic and Health Survey (DHS) reported that the overall prevalence of anemia was 35% among women of reproductive age (15-49 years) and 43% among pregnant women [22]. About 60% of children (6-59 months) were anemic, with prevalence rates over 70% in some provinces [22]. For both women of reproductive age [23,24], and children [25,26] anemia can have serious consequences. Causes of anemia in the D.R.Congo include malaria [27], parasitic helminths and other infections [28], sickle cell haemoglobin [29,30] as well as iron, zinc, folate, vitamin B12, vitamin A, and other micronutrient deficiencies can also contribute to anemia [31].

In Africa, especially in the D.R.Congo, most traditional complementary foods, including porridges are usually made from cereal/root crops based characterized with low nutrient (protein, zinc and Iron) bioavailability due to the presence of multiple anti-nutrients [32,33]. According to a report by Ferguson and Darmon [34], when the nutrient densities of complementary foods fed to 6-11-month-old infants in many developing countries are compared with WHO recommended levels, less than 15% of the 115 foods examined achieved the recommended nutrient density levels for iron and zinc [34]. Enriched complementary foods are needed to fill the gap between the total nutritional needs of the child and the amounts provided by breast milk [5].

There is currently, a lot of interest in the mushroom in many parts of the world [35,36,37,38,39] and especially in Africa [8,40,41,42,43,44], including the Democratic Republic of Congo. Fruit bodies of about 200 mushroom species are consumed throughout the world [40], due to their delicate taste, flavor and health-giving properties [45,46], and are an important source of income in both developing and developed countries [47,48,49].

Mushrooms are rich source of protein [8,42,50]. In mushroom fruiting bodies, all essential amino acids are present [51]. Mushrooms are also good sources of vitamins like riboflavin, biotin and thiamine [52] and minerals including zinc, Iron, calcium, magnesium, potassium and phosphorus [8,42,53,54,55,56]. These are low in fat and energy, that make them a useful contribution to mineral and vitamin intake, particularly the B vitamins and vitamins D and K, and in some cases vitamins A and C [57,58,59]. Appreciable amount of dietary fiber is present in their fruiting bodies which are important for the regulation of physiological functions in human beings like regulation of digestive tract [60,61].

Some mushrooms are reputed to possess antiallergic, anti-cholesterol, anti-tumour and anti-cancer properties [62]. Moreover, mushrooms are low in nucleic acid contents which make them an ideal food for patients suffering from diabetes, obesity and hypertension [63]. Some authors reported that trace element concentrations in mushrooms are considerably higher than those in agricultural crop plants, vegetables, and fruits [64,65].

Mushrooms can provide balancing diet compounds in sufficient quantities for human nutrition [8,41,42,66]. However, despite the nutritional benefits, mushroom have not been adequately tapped in fighting stunting and micronutrients deficiency common in sub-Saharan Africa. Therefore, enriching complementary foods with such nutritious mushrooms like *A. bisporus* and *P. ostreatus* is a way towards reducing protein-energy malnutrition and micronutrient deficiency. Hence, this study focused on development of nutritious complementary porridges from mushroom flour and maize as a technique in order to reduce these problems.

2. Material and Methods

2.1. Collection and Processing of Raw Materials

The raw materials used, processing methods and formulation of the complementary foods were presented in detail in an earlier publication by Ishara *et al.* [8] and briefly described as follows. Two fresh mushroom varieties (*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 varieties 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 sieved using 0.25 mm sieve and stored at room temperature. Finally, the processed raw materials were ground to fine flour and blended to produce complementary porridges. The blended percentage proportions and amount of ingredients are briefly described in the Table 1.

Table 1. Formulation of the complementary porridges and their respective proportions

		Porridges										
Ingredients		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Maize flour	%	100	90	80	70	60	50	90	80	70	60	50
Button flour	%	0	10	20	30	40	50	0	0	0	0	0
Oyster flour	%	0	0	0	0	0	0	10	20	30	40	50
Sugar	g/L	44	44	44	44	44	44	44	44	44	44	44
Water	mL	300	300	300	300	300	300	300	300	300	300	300
Cooking time	Min	25	25	25	25	25	25	25	25	25	25	25

Min: minutes

2.2. Nutritional Composition Analysis

Moisture, protein, fat, fiber, ash and mineral (zinc and iron) content were determined in accordance with Official Methods [67]. 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 [68]. 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 [68].

2.3. In Vitro-Protein Digestibility Determination

The In vitro protein digestibility of the complementary foods was determined following the modified pepsin method described by Mertz *et al.*[69] using pepsin enzyme. The method involved determination of protein content before and after digestion of the samples with pepsin enzyme. Pepsin (1:3000, from HOG Stomach, Loba Chemie) was used for digesting the samples.

Total protein content: The total protein content (before pepsin digestion) of the complementary foods was determined by the Micro-Kjeldahl method [67].

Pepsin digestion: About 1g of the sample was weighed into a centrifuge tube and then suspended in 35 ml of a solution of pepsin (1.5 mg/ml) in 0.1M phosphate buffer (pH 2.0). The mixture was incubated in a water bath shaker (model SHA-C, temp range: RT - 100) with gentle shaking at 37°C for 2h. The tubes were then placed in an ice bath for 30 min to attain a temperature of 4°C followed by centrifugation (Type 20 000, Kokusan corporation, Tokyo, Japan) at 10,000 x g for 15 minutes at 4°C. The supernatant was discarded and 10ml of the buffer solution added, then shaking and centrifugation was done again using the same conditions.

The supernatant was discarded and the residue filtered using a Whatman filter paper n°4. The residue in the centrifuge tube was washed into the funnel with 5ml of the phosphate buffer. The filter paper with the residue was dried for 30 minutes in an oven and then rolled and inserted into a Kjeldahl flask. A blank was prepared in the same way but without a sample.

Digestible protein content: To determine the digestible protein content of the samples, digestion, distillation and titration of the residue were conducted according to the semi-micro Kjeldahl method. A mixture of potassium sulphate and copper sulphate (5.5g) and concentrated sulphuric acid (15ml) were added to the Kjeldahl flask containing 1g of the sample and heated until a green-blue color was formed. The digest was then transferred into a 100-ml volumetric flask and topped up with distilled water. 10mL of the diluted digest was pipetted into a distillation flask, 15mL of 40% NaOH added and then distilled into 4% boric acid. Finally, the distillate was titrated with 0.02N HCl.

The digested protein of sample was calculated by subtracting residual protein from total protein of the sample:

$$Protein\ digestibility(\%) = \left(\frac{A-B}{A}\right)*100$$

Where

A: Protein content in the sample before pepsin digestion or total protein

B: Protein content in the sample after pepsin digestion

(A-B): digested protein.

2.4. Total Titratable Acidity (TTA) and pH Determination

Total titratable acidity (TTA) and pH were measured for day1 and day2 according to the AOAC [67]. The pH values of the complementary porridges were determined in triplicate by a pH-meter. Five (5) grams of samples was mixed with 25ml distilled water. The mixture was allowed to stand for 15 minutes, shaken at 5 minutes intervals, centrifuged at 3000 rpm for 15 minutes. 10ml aliquots (triplicate) were titrated against 0.1 M NaOH using 1 % phenolphthalein as indicator. Titratable acidity was expressed as grams lactic acid per 100g of samples [70].

2.5. Viscosity Determination

Viscosity of foods has received considerable attention as one of the important sensory attributes [71,72]. An Ostwald viscometer was used to measure the viscosity of porridges according to the method of Arukwe et al [73]. The sample was suspended in distilled water and mechanically stirred at room temperature (25°C).

2.6. Statistical Analysis

One-way analysis of variance (ANOVA) was used to determine the effect of mushroom flour addition on nutritional and physical attributes of the complementary porridges using Genstat version 14. Least Significant Difference (LSD) test ($P<0.05$) for means separation and the Pearson's correlation were done using Statistix 8.0.

3. Results and Discussion

3.1. Nutrient Density of Different Complementary Porridges

The results on chemical composition and micronutrients of different maize meal porridges supplemented with mushroom (*Agaricus bisporus* and *Pleurotus ostreatus*) are summarized in Table 2, significantly differed ($p<0.05$) according to the flour type. Increasing both button and oyster mushroom content resulted in increasing of protein, micronutrients (zinc and iron) and fiber. Unlike protein, micronutrients and fiber, increasing mushroom content resulted in decreasing of fat, carbohydrates and energy.

The protein density in Figure 1 for all supplemented porridges increased from 4.63 (control) to 13.91%, this gives an additional nutritional value to the maize meal porridges and indicates that these formulated porridges are an ideal source of protein. Similar results were obtained by Ishara *et al.* *[8]*, they reported that protein content of maize flours increased with increasing mushroom content. The replacement of wheat flour by mushroom powder resulted into increasing the protein content of the bread as reported by Okafor *et al.* [74]. An increase in vegetable soup powder supplemented with mushroom was also observed by Farzana *et al.* [75]. Similarly, adding mushroom flour to cassava and wheat flours increases the protein levels [76].

Table 2. Nutrient density of different complementary porridges

Porridges	MC%	Fiber%	Fat%	Protein%	CHO%	Ash%	Energy (Kcal)	Iron (mg/100g)	Zinc (mg/100g)
MP	$77.54^{b}\pm1.16$	$0.27^{g}\pm0.12$	$2.17^{a}\pm0.31$	$4.64^{h}\pm0.53$	$15.30^{a}\pm1.15$	$0.09^{f}\pm0.03$	$99.25^{a}\pm4.5$	$2.51^{g}\pm0.05$	$2.42^{g}\pm0.08$
Button 10%	$78.25^{b}\pm1.67$	$0.34^{efg}\pm0.06$	$1.92^{b}\pm0.04$	$5.19^{gh}\pm0.18$	$14.06^{ab}\pm1.42$	$0.10^{ef}\pm0.21$	$94.27^{ab}\pm5.93$	$3.43^{ef}\pm0.03$	$2.66^{f}\pm0.11$
Button 20%	$81.47^{a}\pm5.32$	$0.40^{def}\pm0.04$	$1.79^{bc}\pm0.04$	$6.50^{fg}\pm0.3$	$9.70^{cde}\pm4.99$	$0.11^{def}\pm0.12$	$80.92^{b}\pm1.52$	$3.93^{de}\pm0.02$	$2.9^{e}\pm0.06$
Button 30%	$78.66^{ab}\pm0.62$	$0.51^{cd}\pm0.08$	$1.57^{de}\pm0.07$	$7.64^{ef}\pm0.44$	$11.60^{bcd}\pm0.3$	$0.13^{de}\pm0.01$	$91.10^{ab}\pm3.09$	$4.66^{c}\pm0.49$	$3.39^{c}\pm0.15$
Button 40%	$78.46^{ab}\pm1.66$	$0.72^{ab}\pm0.14$	$1.41^{e}\pm0.1$	$10.07^{c}\pm0.98$	$8.79^{def}\pm2.51$	$0.15^{bc}\pm0.1$	$88.09^{ab}\pm7.24$	$5.86^{b}\pm0.08$	$3.58^{c}\pm0.11$
Button 50%	$78.05^{b}\pm1.61$	$0.85^{a}\pm0.02$	$1.19^{f}\pm0.04$	$11.78^{b}\pm0.62$	$7.78^{ef}\pm1.41$	$0.19^{a}\pm0.26$	$88.97^{ab}\pm7.03$	$6.73^{a}\pm0.61$	$3.89^{ab}\pm0.07$
Oyster 10%	$79.25^{ab}\pm0.3$	$0.32^{fg}\pm0.02$	$1.87^{b}\pm0.07$	$6.18^{g}\pm0.87$	$12.35^{abc}\pm1.07$	$0.10^{ef}\pm0.01$	$90.99^{ab}\pm1.35$	$3.13^{g}\pm0.14$	$2.79^{ef}\pm0.09$
Oyster 20%	$77.96^{b}\pm0.48$	$0.37^{efg}\pm0.07$	$1.73^{bcd}\pm0.06$	$8.58^{de}\pm1.22$	$10.92^{bcde}\pm1.97$	$0.11^{def}\pm0.41$	$93.55^{ab}\pm3.07$	$3.53^{ef}\pm0.11$	$3.13^{d}\pm0.07$
Oyster 30%	$79.84^{ab}\pm0.17$	$0.46^{de}\pm0.02$	$1.63^{cd}\pm0.05$	$10.01^{cd}\pm0.36$	$7.94^{ef}\pm0.62$	$0.11^{def}\pm0.11$	$86.45^{ab}\pm0.63$	$4.4^{cd}\pm0.28$	$3.49^{c}\pm0.19$
Oyster 40%	$78.07^{b}\pm0.24$	$0.52^{cd}\pm0.05$	$1.61^{cd}\pm0.06$	$11.66^{b}\pm1.75$	$7.78^{ef}\pm1.86$	$0.13^{cd}\pm0.5$	$84.39^{ab}\pm16.36$	$5.61^{b}\pm0.49$	$3.58^{b}\pm0.13$
Oyster 50%	$78.08^{b}\pm0.21$	$0.61^{bc}\pm0.1$	$1.42^{e}\pm0.2$	$13.91^{a}\pm0.89$	$5.88^{f}\pm0.95$	$0.16^{b}\pm0.11$	$91.90^{ab}\pm1.75$	$5.65^{b}\pm0.17$	$4.04^{a}\pm0.13$

Mean values (n=3) ±sd. Values in the same column with the same following letter do not significantly differ ($p<0.05$).
MP : Maize porridge ; MC : Moisture content & CHO : carbohydrates.

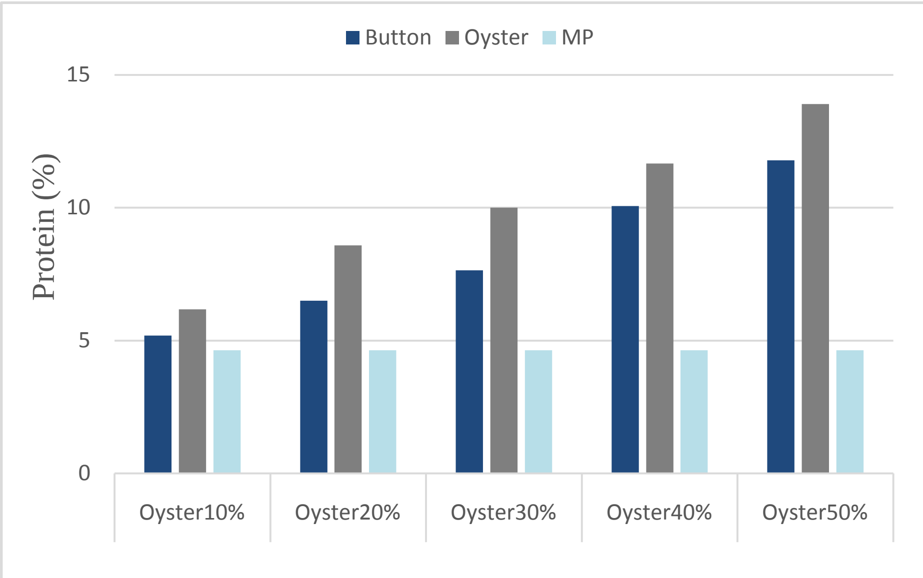

Figure 1. Effect of blending on protein content in fortified porridges

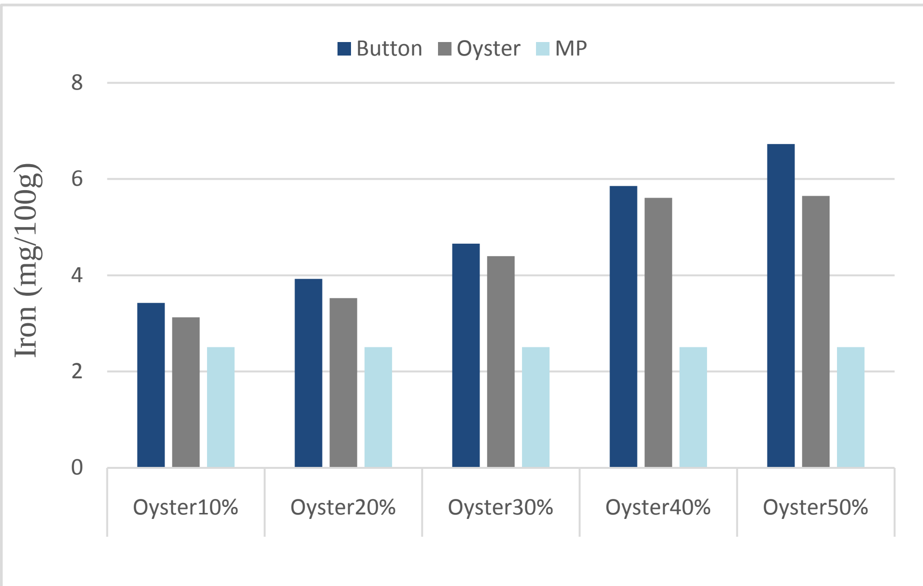

Figure 2. Effect of blending on iron content in fortified porridges

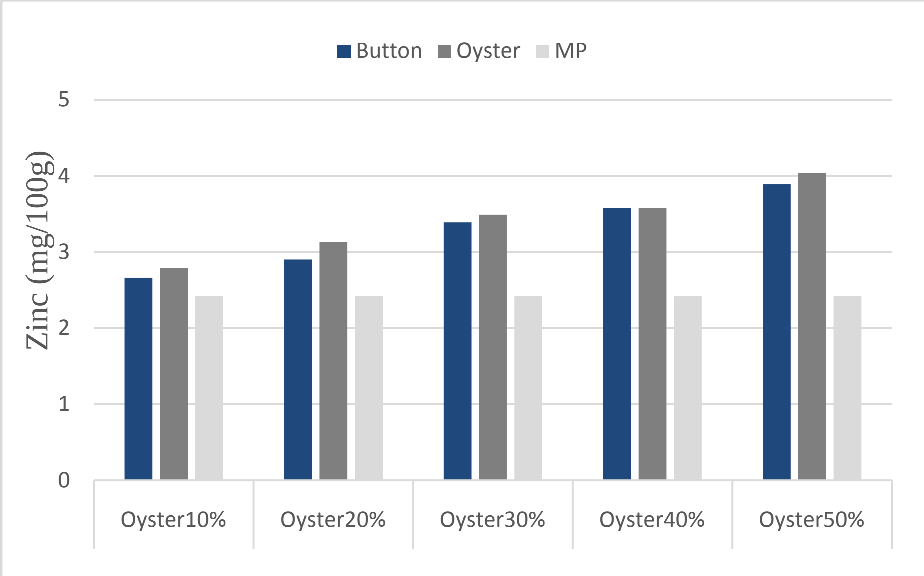

Figure 3. Effect of blending on zinc content in fortified porridges

The effect of mushroom content on iron and Zinc content of the supplemented porridges is shown by Figure 2 and Figure 3 respectively. The mineral content increased from 2.42 (control) to 4.04 mg/100g and from 2.51(control) to 6.73mg/100g for zinc and iron respectively for both mushroom species. There was a significant difference ($p<0.05$) in the samples. The results of this study on the iron and zinc content showed that the complementary porridges meet the daily minerals (zinc and Iron) intake, which is 4mg and 4.6mg for a 12 months old child [77], thus, the maize meal porridge fortified wish mushroom could help in providing micronutrients and protein to reduce the protein malnutrition and micronutrient deficiencies. Iron is important in haemoglobin formation, oxygen and electron transport in the human body [78]. 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 [79]. Infants of mothers with prenatal iron deficiency may also be at risk, even if their birth weight is normal [79].

Iron deficiency is the most common cause of anaemia [80], and 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 [81]. 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 [81]. Low liver reserves of zinc at birth may predispose some infants to zinc deficiency [82], similar to the situation for iron [79]. However, it can be concluded from the results that the maize porridges fortified with mushroom can contribute significant amount of zinc and Iron to the infant and women especially pregnant women. A strong positive correlation was observed between the protein and iron ($r=0.81$) and Zinc ($r=0.93$) content in Table 4. The crude fiber content increased from 0.27 (control) to 0.85% in supplemented porridges with increasing mushroom content for both button and oyster. There is evidence that dietary fiber has a number of beneficial effects related to its indigestibility in the small intestine.

The total fat content slightly decreased from 2.17 (control) to 1.42% by adding mushroom flours in all fortified porridges. This is indicating that it's possible to include mushroom flour into maize flour without affecting the nutritional fat of the maize meal porridges. However, the fat content in this study didn't meet the Dietary Reference Intakes (DRI) for fat which ranges from 5-14g per day for a 7-12 months old child [77]. And were lower compared to the values of the other complementary foods which could be a result of the corresponding lower fat contents in the respective complementary foods [83]. Thus, the lipid density of complementary foods can be enhanced to a higher level through addition of a small quantity of fat/oil during the preparation of the complementary porridge [10,84]. This can also help to enhance the energy density without resulting in an overly thick preparation of the porridge [84].

The results for carbohydrate density in this study decreased from 15.3 (control) to 5.88 %. There is no recommended level of carbohydrate (CHO) density for plant-based complementary foods by Codex Alimentarius Comission [85]. The recommended range of carbohydrate is 9-14% as reported by Koletzko *et al.* [86]. The higher carbohydrate values in the complementary foods is an advantageous to infants as the sugars produced can impart more sweetness to the complementary porridge thereby enabling the infant to take more of the food per feeding and minimize addition of table sugar during preparation of the porridge [87]. However, sugar can be added to increase the sugar content.

The energy density of the developed porridges decreased from 99.25 (control) to 88.97 Kcal/100g with no significant difference ($p<0.05$) among the values. According to the Codex standard for processed cereal-based foods for infants and young children according to the Codex Alimentarius Commission [85], the energy density of a cereal-based complementary food should be ≥ 80 kcal/100g. Therefore, the complementary porridges considerably met the minimum stipulated daily energy requirement for the infants. Therefore, a 6-8-month-old, infant can fulfill its energy requirement from the complementary foods by consuming two to three times a day with the option of adding snacks once or twice, which depends on the child's appetite and signs of hunger and satiety [88,89].

Table 3. Coefficients of the Pearson's correlations between physico-chemical properties of the fortified porridges

	MC%	Fiber%	Fat%	Protein%	CHO%	Ash%	Energy	Iron	Zinc	IVPD	pH1	pH2	TTA1	TTA2	V1
Fiber%	0.01														
Fat%	0.05	**-0.89**													
Protein%	-0.13	**0.71**	**-0.74**												
CHO%	-0.45	**-065**	**0.62**	**-0.82**											
Ash%	-0.18	0.23	-0.19	0.24	-0.19										
Energy	**-0.81**	-0.26	0.21	-0.16	**0.62**	-0.24									
Iron	-0.09	**0.87**	**-0.86**	**0.81**	**-0.68**	0.28	-0.25								
Zinc	-0.08	**0.77**	**-0.85**	**0.93**	**-0.78**	0.22	-0.26	**0.89**							
PD	-0.03	**0.68**	**-0.68**	**0.78**	**-0.69**	0.29	-0.22	**0.82**	**0.81**						
pH1	0.04	**-0.59**	0.51	-0.09	0.06	-0.19	0.07	-0.52	-0.24	-0.38					
pH2	0.03	-0.46	0.41	0.03	-0.04	-0.14	0.02	-0.41	-0.11	-0.29	**0.92**				
TTA1	0.08	0.52	-0.45	-0.05	-0.01	0.17	-0.10	0.38	0.11	0.29	**-0.85**	**-0.89**			
TTA2	0.13	0.51	-0.44	-0.05	-0.02	0.13	-0.14	0.37	0.11	0.28	**-0.82**	**-0.85**	**0.99**		
V1	0.04	-0.45	**0.59**	**-0.87**	**0.75**	-0.52	0.24	**-0.64**	**-0.84**	**-0.67**	-0.12	-0.23	0.27	0.26	
V2	0.03	-0.55	0.44	**-0.83**	**0.81**	-0.57	0.32	-0.57	**-0.79**	**-0.73**	-0.16	-0.34	0.25	0.22	**0.94**

Mean values (n=3) ±sd. Values in the same column with the same following letter do not significantly differ (p<0.05).
MP: Maize porridge; MC: Moisture content; CHO: carbohydrates; IVPD: In Vitro-Protein digestibility; TTA: Total titratable acidity; V1: viscosity day1 & V2: viscosity day2.

The moisture content in all the porridges studied was higher than 77%, indicating microbial activity. There was no significant difference ($p<0.05$) among the different developed porridges. The ash content increased from 0.09 (control) to 0.19% in fortified porridges. The results showed that the ash content increased with increasing mushroom inclusion. This in agreement with the findings of Buight [52] and Ishara *et al.* [8], they reported that mushroom is rich in mineral elements.

3.2. Physico-chemical Properties of Different Complementary Porridges

The results on protein digestibility, total titratable acidity (TTA), pH and viscosity of different maize meal porridges fortified with mushroom (*Agaricus bisporus* and *Pleurotus ostreatus*) are presented in Table 4, and differed significantly ($p<0.05$) as influenced by the mushroom species and ratios. Increasing both button and oyster mushroom content resulted in increasing of protein digestibility and decreasing of the viscosity. However, adding oyster flour resulted in increasing of the pH and decreasing of the TTA. On the other hand, increasing the button flour resulted in decreasing of the pH and increasing of the TTA. A strong negative correlation ($r=-0.85$) was observed between the pH and the TTA in Table 3.

3.2.1. The in Vitro-protein Digestibility

Protein nutritional value is dependent on the quantity, availability and digestibility of essential amino acids [90]. Digestibility is considered as the most important determinant of protein quality [91]. The in vitro protein digestibility (IVPD) is a measure of the proportion of nitrogen that would be absorbed after ingestion of a protein containing food [92]. In this study, the in vitro protein digestibility of the fortified porridges increased from 63.97 to 75.14% in Table 4. Ogodo *et al.* [93] reported an increase of 23.34% of in-vitro protein digestibility from 61.28 to 84.62% in LAB-consortium from maize fermented. The protein quality of cereals is further compromised because of low content of amino acids [94]. For instance, the lysine content of maize, which is the most limiting amino acid is about 3% [95], which is less than half the concentration required during complementary feeding of 5.2% [91]. The amino acid lysine is not only important as an essential amino acid but it is also the first limiting amino acid in cereals and tubers [95]. It is also the most susceptible to damage during cooking, processing and storage [96]. This is because the lysine can undergo reaction with many compounds including reducing sugars (Maillard reaction), fats, vitamins, polyphenols and food additives [97].

The in vitro protein digestibility in this study is higher compare to the results (performed using digestion cells for 6hours) reported by Ejigui *et al.* [98] in fermented maize with germinated peanuts (58.1%), in fermented maize with roasted peanuts (56.3%), in fermented maize with germinated and roasted peanuts (54%), in fermented maize with germinated beans (50.8%), in fermented maize with roasted beans (36.6%), and in fermented maize with germinated and roasted beans (51%). In this study, the increase of the in vitro protein digestibility (11.17%) was probably due to the protein quality of the mushroom [99], and heat [100,101]. According to Muyonga *et al.* [101], the nature of the change in protein digestibility resulting from heat treatment seems to relate partly to the extent of formation of complexes between proteins and other grain components and the level of matrix disintegration, which impacts the access of proteolytic enzymes to protein bodies. Heat treatment may also increase lysine availability and protein digestibility due to unfolding of protein molecules that favours enzymatic attack and reaction with the test reagent [100]. The protein present in mushrooms are in forms that are easily digestible and of better quality than many legumes sources such as soybeans, peanut, and protein yielding vegetable foods [102].

Table 4. Physico-chemical properties of different fortified porridges

Porridges	IVPD%	pHday1	pHday2	TTAday1(%)	TTAday2(%)	V1(Pa.s)	V2(Pa.s)
MP	$63.97^{f}\pm3.49$	$6.19^{bc}\pm0.03$	$6.15^{ab}\pm0.02$	$1.38^{efg}\pm0.16$	$1.55^{def}\pm0.18$	$5.73^{a}\pm0.22$	$5.33^{a}\pm0.12$
Button 10%	$68.56^{de}\pm1.62$	$6.17^{bcd}\pm0.1$	$6.07^{bc}\pm0.06$	$1.39^{efg}\pm0.18$	$1.58^{de}\pm0.2$	$5.22^{b}\pm0.14$	$4.79^{b}\pm0.21$
Button 20%	$71.76^{bc}\pm1.01$	$6.13^{d}\pm0.04$	$5.9^{de}\pm0.1$	$1.66^{cd}\pm0.14$	$1.87^{bc}\pm0.17$	$4.9^{c}\pm0.18$	$4.49^{c}\pm0.15$
Button 30%	$72.76^{abc}\pm2.02$	$6.02^{e}\pm0.02$	$5.85^{e}\pm0.13$	$1.78^{bc}\pm0.01$	$1.98^{b}\pm0.02$	$4.72^{cd}\pm0.09$	$4.27^{c}\pm0.11$
Button 40%	$74.44^{ab}\pm0.57$	$6.01^{e}\pm0.01$	$5.8^{ef}\pm0.1$	$1.85^{b}\pm0.12$	$2.01^{b}\pm0.15$	$4.54^{de}\pm0.14$	$4.14^{de}\pm0.09$
Button 50%	$74.99^{a}\pm1.86$	$5.9^{f}\pm0.1$	$5.7^{f}\pm0.1$	$2.08^{a}\pm0.01$	$2.26^{a}\pm0.03$	$4.33^{e}\pm0.19$	$3.79^{e}\pm0.25$
Oyster 10%	$67.41^{e}\pm1.37$	$6.20^{bc}\pm0.01$	$6.16^{ab}\pm0.08$	$1.35^{fg}\pm0.01$	$1.49^{def}\pm0.02$	$4.69^{cd}\pm0.14$	$4.17^{d}\pm0.18$
Oyster 20%	$70.55^{cde}\pm2.13$	$6.21^{bc}\pm0.02$	$6.18^{ab}\pm0.01$	$1.32^{g}\pm0.06$	$1.46^{ef}\pm0.05$	$4.34^{e}\pm0.12$	$3.75^{e}\pm0.07$
Oyster 30%	$71.70^{bcd}\pm2.31$	$6.22^{abc}\pm0.02$	$6.19^{ab}\pm0.02$	$1.28^{gh}\pm0.08$	$1.44^{ef}\pm0.11$	$3.86^{f}\pm0.15$	$3.41^{f}\pm0.13$
Oyster 40%	$73.18^{abc}\pm0.3$	$6.23^{ab}\pm0.03$	$6.2^{a}\pm0.01$	$1.22^{gh}\pm0.1$	$1.41^{f}\pm0.11$	$3.65^{fg}\pm0.08$	$3.25^{f}\pm0.12$
Oyster 50%	$75.14^{a}\pm1.83$	$6.26^{a}\pm0.02$	$6.23^{a}\pm0.02$	$1.19^{h}\pm0.01$	$1.36^{f}\pm0.05$	$3.56^{g}\pm0.07$	$3.09^{g}\pm0.14$

Mean values (n=3) ±sd. Values in the same column with the same following letter do not significantly differ ($p<0.05$).
MP: Maize porridge; IVPD: In Vitro-Protein Digestibility; TTA: Total Titratable Acidity; V1: Viscosity day1 & V2: Viscosity day 2.

Griffith *et al.* [103] reported an improvement of 12% to 14% in digestibility in pearl millet–peanuts blends and pearl millet–cowpea blends due to germination and fermentation. In vitro protein digestibility in maize-mushroom porridges showed a significant negative correlation with viscosity (r = -0.67 and -0.73, respectively) in Table 3. This suggests that a higher in vitro protein digestibility can be expected from complementary porridges with lower viscosity.

3.2.2. Total Titratable Acidity (TTA) and pH

The results on the total titratable acidity and pH in Table 4, indicate that the TTA values increased with increasing the button flour content and decreased with increasing the oyster flour content for both day 1 and day 2. According to pH, the pH values decreased with increasing the button flour content and increased with adding the oyster flour for both day 1 and day 2. There was a strong negative correlation (r=-0.89) between the TTA values and pH values. Fan *et. al.* [104] reported that changes in titratable acidity do not necessarily have an effect on pH values. A strong positive correlation (r=0.92 and r=0.99) was observed between pH1 and pH2, and between TTA1 and TTA2. The TTA values increased from 1.38 (control) to 2.08% and from 1.55 (control) to 2.26% with adding button content for day1 and day2 respectively. This probably due to some organic acid that the button might be having. On the other hand, adding the oyster flour resulted in decreasing the TTA values from 1.38 (control) to 1.19% and from 1.55 (control) to 1.36% for day 1 and day 2 respectively. Adding button flour resulted in decreasing the pH values from 6.19 (control) to 5.9 and from 6.15 (control) to 5.7 for day1 and day2 respectively. Opposite results were observed with adding oyster flour, which resulted in increasing the pH values for day1 and day2 from 6.19 (control) to 6.26 and from 6.15 (control) to 6.23 respectively.

A decrease in pH for overall porridges was observed for day 2 compare to the pH values for day 1, this due to the probable fermentation and growth rate of lactic acid bacteria might have started, lowering thus the pH values [105,106]. Similar results were reported by Akpinar-Bayizit *et al.* [107] saying that generally, acidity increased as fermentation advanced.

3.2.3. Viscosity

Viscosity of foods has received considerable attention as one of the important sensory attributes [71,72]. The viscosity of the fortified porridges in this study as shown in Table 4 decreased by adding both button and oyster flours. The viscosity of maize meal porridge decreased from 5.73 (control) to 4.33 Pa.s and from 5.33 to 3.33 Pa.s by adding 50% button flour for day1 and day2 respectively. On the other hand, the viscosity decreased up to 3.56 Pa.s (day 1) and to 3.09 (day 2) by increasing oyster flour content. There was a strong linear negative correlation between the viscosity and the protein (r=-0.87), iron content (r=-0.64), zinc content (r=-0.84) and the in vitro-protein digestibility (r=-0.73). Furthermore, a strong linear positive correlation was the viscosity and the fat (r=0.59), and the carbohydrate (r=0.81). These results are similar with the results reported by Muoki [94], showing a decrease of the viscosity in cassava-soy flour porridges due possibly to depolymerisation of starch, as the flour is also starchy.

The key elements characterizing African traditional complementary porridges include high viscosity, low energy density [108] and poor protein quality [98]. These attributes have often been identified as causative factors of protein-energy malnutrition [109]. The fortified porridges studied can contribute to solve this problem, they have decreased the viscosity and increased the protein and mineral content of the maize meal porridges. The viscosity of porridges that can be eaten by children (age not specified) to be 1-3 Pa.s according to Moshe and Svanberg [108]. Tréche and Mborne [110], found the viscosity of porridges fed to Congolese children aged 4-11months to be 0.5-2.8 Pa.s. The cereal-cassava complementary porridges (target age not specified) showed a viscosity of about 3 Pa.s [111]. Adding mushroom to the maize meal porridge help to reduce the viscosity close to the proposed viscosity (about 1-3 Pa.s) of the complementary porridges for consumption by young children [108].

The higher viscosity observed in the control (maize meal porridge unfortified) is probably due to the gelatinization [111] that increases the viscosity as a result of structural changes occurring in starch granules [93,112,113]. These changes include absorption of water, irreversible swelling of the starch granules, melting of crystallites and leaching out of amylose [114]. This corresponds to increase in viscosity [111,115]. During cooling at about 40°C retrogradation occurs [116]. Both amylose and amylopectin associate during this process with amylose retrogradation occurring at a faster rate than that of amylopectin [117,118]. Retrogradation tends to increase viscosity of porridge due to molecular reassociation [93,119]. Presence of other ingredients such as lipids may affect the viscosity [120]. Kuar and Singh [121] found fatty acids to increase the viscosity of rice flour pastes. Similarly, Wokadala *et al.* [122] found an increase in viscosity during long pasting of teff and maize starch in the presence of stearic acid. Bejosano *et al.* [123] reported inclusion of 9% *amaranthus* and buckwheat proteins to increase the peak viscosity of maize starch paste.

Fermentation has limited effect on viscosity of porridge and energy density [111]. However, information on the effect of fermentation on viscosity is conflicting as some workers reported that fermentation did not reduce viscosity of porridges [111,124]. Lorri and Svanberg [125] reported a reduction in viscosity due to fermentation as indicated by an increase in solids content of porridge from 7% unfermented sorghum porridge to 15% in fermented porridge. The overall effect of fermentation on viscosity of porridge depends on the extend of breakdown of starch to simple sugars; which do not swell during cooking. In the present study, the values of the viscosity decreased (day2) compare to the values of day 1.

4. Conclusion

This study has demonstrated significant ($p<0.05$) difference in the nutritional and physical attributes of the different porridges investigated. Increasing both *A. bisporus* and *P. ostreatus* flour content resulted in increasing of protein, in vitro-protein digestibility, micronutrients (zinc and iron) and fiber. Furthermore, increasing mushroom content resulted in decreasing of fat, carbohydrates, energy and viscosity. However, adding *P. ostreatus* flour resulted in increasing of the pH and decreasing of the Total titratable acidity (TTA). On the other hand, increasing the *A. bisporus* flour resulted in decreasing of the pH and increasing of the TTA. A strong significant ($p<0.05$) linear correlation (-0.73) was observed between the in vitro-protein digestibility and the viscosity in maize-mushroom porridges. Considering the protein content, micronutrients content, the in vitro-protein digestibility and the decreased viscosity, these fortified porridges can highly contribute to reduce the protein malnutrition and micronutrients deficiency.

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