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Nutritional Evaluation of Maize Ogi Supplemented with the Sclerotia of *Pleurotus tuber-regium* Fr. (Sing)

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Abstract

Maize-ogi, a popular slurry taken in most parts of sub-sahara Africa was supplemented with the sclerotium of *P. tuber-regium*. The sclerotium was employed to supplement maize ogi at 10 – 50% levels using the traditional protocol of production. Supplementation of maize-ogi with 20% sclerotium brought about a 36.80% improvement in the fibre content of the ogi while a 30% supplementation gave a 41.72% improvement in fibre content. The ash content was not significantly affected by the supplementation. This may be attributable to the fact that maize contains more ash than the mushroom. Also, the 20% and 30% sclerotium supplementation gave a 1.90% and 15.24% improvement in the fat content of the final products in comparison to the control. Furthermore, the addition of 20% and 30% sclerotium to maize-ogi improved the protein content of the final products by 8.97% (M20) and 17.24% (M30) respectively. With respect to vitamin B content, results showed that supplementation of maize-ogi with 20% *P. tuber-regium* sclerotium did not have a statistically significant impact on the vitamin content of the products. However, a 30% supplementation gave an increase of 133%, 314% and 233% in thiamine, riboflavin and niacin contents of the final products when compared with the control. The antioxidant potentials of the ogi was significantly increased by the supplementation, especially with 30% sclerotium supplementation.

Keywords

Maize-ogi, Sclerotium, *Pleurotus tuber-regium*, Supplementation

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1. Introduction

Ogi is a popular staple food of tropical West African countries. The traditional method of ogi production involves fermenting the grains through chance inoculation [1]. Basically, any of millet (*Pennisetum typoideum*), sorghum (*Sorghum vulgare*) and maize (*Zea mays*), are steeped in water for 2-3 days. Then it is wet-milled and sieved using muslin cloth, screen mesh or any other material depending on the texture preference of the producer. The sieviate is allowed to continue to ferment depending on the sourness preference of the producer while the pomace is fed to local chicken or thrown away. It is the sieviate that is now cooked to make "Pap". Due to this method of preparation, a lot of nutrients are lost during the process [2]. The percentage protein losses associated with the use of traditional method of processing for sorghum, millet and maize ogis has been documented to be 70.88%, 61.14% and 75.59% respectively [3]. Despite the poor nutritive value of Ogi, so many homes in west Africa still continue to depend on it to wean their babies or as the food of choice for breakfast [4]. Sadly, children that have been weaned exclusively with 'ogi' are known to suffer from marasmus [5]. The grave danger this portends for the child becomes more obvious in the face of the fact that a child's allround development is dependent on the

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quality of his diet especially during the first twenty-four months of his life, which is the range within which most babies are weaned [6].

Many researchers have made several efforts to improve the nutritive quality of 'ogi' using processes like fortification, supplementation and modification of production process. Some of these efforts include but not limited to the addition of pawpaw, groundnut, soya bean, okra seed, amino acids, pigeon pea, crayfish, sesame seed to mention but a few to supplement 'ogi' [7-15]. The protein quality of 'ogi' has also been increased by the employment of lysine- and methionine-producing microorganisms as starters [1]. This is due to the fact that most cereals, especially maize are very low in lysine and tryptophan [16-18].

Though some of the products of the efforts of the workers above produced 'ogis' with good nutritive value, but many of them ended up with poor rheological and organoleptic qualities thereby making them unattractive to consumers [19].

Furthermore, some of the products were rejected because of the nature of what was used to supplement them, e.g natural slimy nature of Okra, aroma and flavour of sesame seed, inadequate carbohydrate in pigeon pea etc. Consequently, effort must continue to find ways of producing highly nutritious ogi that will be favourably accepted by consumers.

Therefore, this effort was undertaken to improve the nutritive quality of 'ogi' by supplementing it with the sclerotia of *Pleurotus tuber-regium*, a nutritious Oyster mushroom. The sclerotium is a part of the mushroom that is produced underground like a tuber. It is a tightly and closely woven dense aggregations of fungal tissue which can be either spherical, ovoid or shapeless and may be as large as up to 30 cm (11.8 inches) in diameter [20-23]. The sclerotium has been found to help the mushroom cope with unfavourable conditions such as extremely low temperatures, drought, microbial attack, or absence of substrate [24]. It also serves as a method to help the mushroom sustain its existence through difficult conditions. Chen and Huang [25] defined sclerotium as a tightly woven structure of non-fertile or sterile mycelial. It is usually hard when dry and may be viable for seven years after harvest. The sclerotium is dark brown on the outside and white on the inside. It is usually produced under the ground or on decaying logs in the forest. Nutritionally, it contains 22% protein, 1.06% lipid, 2.97% ash, 63.03% CHO, 10.80% fibre, 349.98 calorific value and 0.21% ethanol soluble sugar. [26].

2. Research Significance

This work will provide a basis for the use of the sclerotium of *P. tuber-regium* in the improvement of the nutritive content of 'Ogi' and other fermented low-nutreint foods. It will also help researchers, especially in the field of nutraceuticals to take advantage of the huge medicinal benefits of the mushroom. This effort will in the long run create a huge market for the sclerotium of this mushroom and in turn improve the living conditions of rural farmers who are the main source of it in most African countries. It can also stimulate an increased cultivation of the mushroom which will lead to a safer and cleaner environment since the lignocellulosic wastes which normally will constitute environmental pollution would have been employed in its cultivation.

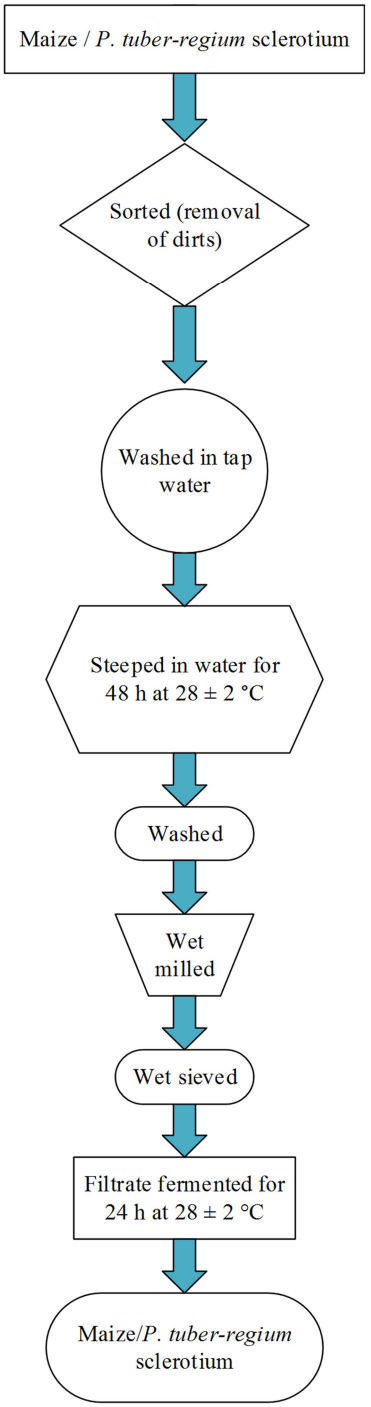

Figure 1. Production steps for maize/sclerotia ogi.

3. Materials and Methods

3.1. Sample Collection

The sclerotia used for this work, with the ascension number MW376907 were cultivated, characterized molecularly and registered [27]. The maize grains were purchased from Ajoke Market, Oka Akoko in Akoko southwest Local govt Area of Ondo State, Nigeria.

3.2. Preparation of Samples

The maize grains were carefully sorted to rid them of impurities and stones. The brownish outer layer of the sclerotia was peeled while the sclerotia were kept in clean polyethylene bags for further work. Then the sclerotia were combined with the maize grains as shown in table 1 [4].

Table 1. Supplementation ratios of *P tuber-regium* sclerotia and maize.

Sample ratio	Maize (g)	*P. tuber-regium* (g)	Codes
100:0	1000	0	M
90:10	900	100	M10
80:20	800	200	M20
70:30	700	300	M30
60:40	600	400	M40
50:50	500	500	M50

The maize grains and sclerotia were washed three times in tap water. They were then soaked in water in the ratio of 1:2 (w/v) in plastic containers with lids. They were allowed to ferment (primary fermentation) for 48 h. This was followed by washing, wet-milling and sieving using a muslin cloth. The filtrates were allowed to sendiment and ferment for another 24 h (figure 1) before samples were taken for analysis [15].

3.3. Proximate Analysis

Analysis such as ash, fat, fibre, crude protein, and moisture and fibre were carried out using the procedure of AOAC (2003) [28]. Protein contents were determined by standard micro Kjeldahl method. The total nitrogen estimated was multiplied by 6.26. Ash contents were calculated by calculating the difference in weight of ignited samples before and after being subjected to a temperature of 600°C in a muffle furnace for 6 h. Crude fat was evaluated using Soxhlet extraction method Moisture content was calculated by drying already determined weights of the samples at 103-105°C. These samples were later cooled, oven-dried and weighed until same weights were recorded. Loss of ignition was applied to determine crude fibre. Carbohydrate contents were calculated by differences: % CHO = 100 - (sum of the percentages of moisture, ash, fat, protein and crude fibre).

3.4. Evaluation of Minerals

The mineral contents of the samples were evaluated by first digesting them with a solution containing HNO_3 and distilled water in the ratio 3:1. This was done to break the minerals away from the complexes in which they exist. Then the AAS was standardised with the pure forms of the selected minerals bore readings were taken. AOAC [2005) [29].

3.5. Analysis of B Vitamins

Selected B Vitamins such as B_1 (thiamine), B_2 (riboflavin) and B_3 (niacin) were evaluated using the method described by AOAC (2005).

3.6. Sensory Evaluation

The organoleptic assessment of the supplemented 'ogi' products was done by 30 untrained panelists. Questionnaires with sensory scores based on a 9-point hedonic scale, where 0 meant dislike extremely and 9 like extremely were distributed to each of the panellists [30]. They were instructed to taste each of the prepared 'ogi' samples and rinse their mouths after each tasting. Their feelings about the samples were scored under the following attributes: appearance, sourness, taste, aroma/smell, overall acceptability, flavour and comparability.

3.7. Statistical Analysis

GrapgPad Prism version 5.01 was used to analyse data generated. Further analysis was carried out on some of the data obtained using ANOVA at $\alpha = 0.05$ level of significance.

Table 2. Proximate composition of maize and *P.* tuber-regium sclerotium.

Parameters (%)	Maize	*P. tuber-regium*
Moisture	9.77±0.09	13.36±0.02
Protein	10.53±0.07	18..29±0.00
Fat	1.87±0.03	6.81±0.02
Ash	1.63±0.07	0.88±0.01
Crude Fibre	3.50±0.06	17.49±0.01
CHO	72.67±0.03	42.17±0.02

Table 3. Antinutrient contents of the sclerotium of *P. tuber-regium.*

Antinutrients	Sclerotium
Tannin (mg GAE/g)	3.63±0.45
Oxalate (mg/g)	0.47±0.03
% Phytate	0.25±0.01
Flav (mg GAE/100g)	53.89±2.89
% Alkaloid	2.28±0.01
% Saponin	0.20±0.00

Table 4. Organoleptic properties of the 'ogi' products.

Products						
Features	**M**	**M10**	**M20**	**M30**	**M40**	**M50**
Colour	81.40	77.70	77.70	85.10	77.70	74.00
Texture	92.50	74.00	77.70	74.00	48.10	59.20
Flavour	81.40	55.50	77.70	62.90	70.30	59.20
Sourness	81.40	62.90	81.40	74.00	62.90	59.20
Aroma	70.30	66.60	74.00	74.00	70.30	62.90
Comparability	70.30	55.50	77.70	70.30	48.10	44.40
Mean±SD	79.55±8.36	65.37±9.26	77.70±2.34	73.38±7.18	62.9±12.38	59.82±9.48

Table 5. Amino acid profile of the sclerotia.

Essential amino acids	Quantity (g/100g)	Non-essential amino acids	Quantity (g/100g)
Arginine	7.05	Alanine	4.26
Histidine	3.78	Asparagine	7.10
Isoleucine	3.52	Cystine	1.51
Leucine	5.21	Glutamic acid	13.44
Lysine	4.75	Glycine	3.21
Methionine	1.59	Serine	3.19
Threonine	4.30	proline	4.29
Valine	5.06	Tyrosine	1.54
Tryptophan	1.78		
Phenylalanine	3.99		

Table 6. Organic acids in the 'ogi' products.

Products	Tartaric acid	Citric acid	Acetic acid	Lactic acid	Malic acid
M	0.22±0.01c	0.02±0.00f	0.08±0.00c	0.13±0.01b	0.10±0.00c
M20	2.33±0.02a	0.04±0.00	0.16±0.01b	0.16±0.01b	0.32±0.02a
M30	1.92±0.01b	0.06±0.00	0.37±0.01a	0.21±0.01a	0.18±0.01b

Values are means ± standard deviation of triplicate determinations. Means having the same superscript along the same column are not significantly different ($p<0.05$) from each other

Table 7. Antinutrient contents of the 'ogi' products.

Products	Antinutrients				
	phenol	**flavonoids**	**Tannin**	**Oxalate**	**Phytate**
M	4.43±0.04d	0.02±0.01b	1.93±0.01d	1.30±0.06a	10.63±0.58b
M20	4.80±0.04c	0.03±0.01ab	2.78±0.01b	1.04±0.06b	7.41±0.00b
M30	5.50±0.04a	0.03±0.01ab	3.92±0.01a	0.72±0.00c	6.59±0.00c

Values are mean ± standard deviation of triplicate determinations. Means having the same superscript along the same column are not significantly different ($p<0.05$) from each other

Table 8. Vitamin B contents of the 'ogi' products.

Products	Vitamins		
	Thiamin ((B1)	**Riboflavin (B2)**	**Niacin (B3)**
M	0.18±0.01b	0.07±0.00b	0.09±0.00b
M20	0.18±0.01b	0.08±0.00b	0.10±0.01b
M30	0.42±0.02a	0.29±0.02a	0.30±0.02a

Values are mean ± standard deviation of triplicate determinations. Means having the same superscript along the same column are not significantly different ($p<0.05$) from each other

Table 9. Mineral contents of the 'ogi' products.

SAMPLES	Ca (mg/100)	P (mg/100)	K (mg/100)	Na (mg/100)	Mg (mg/100)	Zn (mg/100)	Fe (mg/100)	Mn (mg/100)	Cu (mg/100)	Hg (mg/100)	Pb (mg/100)
M	93±0.21c	238±0.17c	446.00±0.22a	72.00±0.21c	254.00±0.19c	0.001±0.00b	-	-	-	-	0.010±0.00
M20	185±0.19b	264±0.17b	422.00±0.22b	88.00±0.21a	288.00±0.19b	0.002±0.00b	-	-	-	-	-
M30	173±0.20a	271±0.21a	416.00±0.21c	86.00±0.22b	320.00±0.19a	0.003±000a	-	-	-	-	-

Values are mean ± standard deviation of triplicate determinations. Means having the same superscript along the same column are not significantly different ($p<0.05$) from each other

Table 10. Proximate composition of the 'ogi' products.

PARAMETERS (%)	M	M20	M30
Moisture	43.58±0.42a	37.03±0.42b	32.61±0.41c
Ash	1.82±0.00b	1.78±0.02c	1.97±0.01a
Fibre	1.63±0.02c	2.23±0.01b	2.31±0.02a
Fat	2.10±0.03b	2.14±0.02b	2.42±0.03a
Crude protein	5.80±0.04c	6.32±0.05b	6.80±0.05a
CHO	45.07±0.41c	50.47±0.41b	53.79±0.42a

Values are mean ± standard deviation of triplicate determinations. Means having the same superscript along the same column are not significantly different ($p<0.05$) from each other ($p \leq .05$).

Table 11. Effects of the Supplementation on the Amino Acids Contents of the 'ogi products.

AMINO ACIDS	SM (g/100g)	SM20 (g/100g)	Percentage improvement (%)	SM30 (g/100g)	Percentage improvement (%)
ARGININE	0.95	1.30	36.84	1.48	55.79
HISTIDINE	0.50	0.69	38.00	0.78	56.00
ISOLEUCINE	0.63	0.8	26.98	3.32	42.86
LEUCINE	2.20	2.46	11.82	5.11	17.73
LYSINE	0.45	0.69	53.33	0.81	80.00
METHIONINE	0.26	0.34	30.77	0.38	46.15
THREONINE	0.5	0.71	42.00	3.21	64.00
VALINE	0.75	1.00	33.33	4.24	50.67
TRYPTOPHAN	0.25	0.34	5.01	0.39	7.87
PHENYLALANINE	0.88	1.08	22.73	1.18	34.09
		Non Essential Amino Acids			
GLYCINE	0.63	0.78	23.81	0.86	36.50
ALANINE	0.43	0.64	48.83	0.76	76.74
SERINE	0.45	0.61	35.56	0.69	53.33
PROLINE	0.29	0.51	75.86	0.61	110.34
ASPARTATE	1.55	1.90	22.58	2.08	34.19
GLUTAMATE	1.43	2.10	46.85	14.50	69.93
TYROSINE	0.96	1.04	5.19	1.07	7.14
CYSTINE	0.18	0.25	4.64	0.29	7.28

Table 12. Antioxidant content of the ogi products.

Products	Antioxidants		
	FRAP	DPPH	OH
M	24.76±0.04c	80.65±0.19c	80.95±6.73a
M20	26.74±0.04b	83.27±0.19b	86.21±0.00a
M30	27.02±0.04a	84.30±0.09a	89.59±1.25a

Values are mean ± standard deviation of triplicate determinations. Means having the same superscript along the same column are not significantly different ($p<0.05$) from each other

4. Results and Discussion

The nutritional inadequacy of 'Ogi' especially with respect to its low protein content is well documented [3]. It therefore means any substance that will be employed in improving its protein content must be rich in protein. Table 2 shows the proximate compositions of the yellow maize variety and the sclerotium used in this work. The sclerotium contains more than three times the quantity of fat in maize. It has more than five times the fibre in maize and two times less the quantity of ash in maize. It is particularly important to note that the sclerotia is almost twice as rich in protein compared to the maize. The poor protein content of maize has been linked to the presence of large amount of prolamins which are known to be limiting in lysine and tryptophan [31]. However, the sclerotia of *P. tuber-regium* is rich in these amino acids, especially lysine, when compared to maize. So it is important that a crop, plant or biological item

used in supplementing any food for nutritional improvement, especially with respect to proteins be established to be rich in the limiting amino acids lacking in the food substance. The amino acid evaluation of the sclerotia shows that it contains high amount of essential amino acids like arginine, leucine, lysine, valine, threonine and histidine. 100g of the sclerotia contains 41.03g of essential amino acids, 38.54g of non-essential amino acids, 3.10g of sulphur-containing amino acids (methionine and cystine) and 7.31g of aromatic amino acids (tryptophan, phenylalanine and tyrosine) (table 5). In the light of these pieces of information, it becomes scientifically reasonable to supplement maize-ogi with the sclerotium of *P. tuber-regium.* The antinutrient contents of the sclerotium are well within safe limits (table 7). In fact, some of these values are far lower compared to what is contained in many legumes which are commonly employed to supplement 'ogi' in Nigeria and most parts of Africa. Only the flavonoid content of the sclerotium is a bit high and this coupled with other antinutrients are responsible for the well documented medicinal benefits of this mushroom. Furthermore, maize is known to be limiting in L-lysine L-tryptophan L-methionine in that order. On the other hand, legumes are known to be limiting in L-methionine in the top position. Therefore, when maize and legume are combined in a diet, methionine can still be nutritionally limiting [32].

As earlier discussed, several efforts have been made to improve the nutritive value of ogi. However, some of the products of those efforts are not available today due to poor acceptance by the consumers. It is therefore important that products of supplementation of Ogi be first subjected to organoleptic assessment before further analysis are carried out on them. The statistical analysis of the organoleptic assessment of the ogi produced by supplementing maize with *P. tuber-regium* sclerotia culminated in the selection of three out of the six samples tasted (table 4). The samples are; M (control), M20 (80g of Maize + 20g of sclerotia) and M30 (70g of Maize + 30g of sclerotia) (table 4). Further evaluations were then carried out on them. The result of the organic acids analysis as shown in table 6 indicates that increased amount of lactic, acetic and tartaric acids correlates positively with the acceptance of the ogi products by the taste panellists. In all cases, there was increased presence of organic acids with higher supplementation. This may be due to the availability of more nutrients which encouraged the growth and multiplication of more organisms in the fermenting maize/sclerotium blends. Table 7 shows the antinutrient contents of the ogi products. The figures are within the safe levels for each of the antinutrients. Maize-ogi is known to be deficient in B vitamins, therefore, the products were screened for some of the common ones i. e B1, B2 and B3. Results showed that supplementation of maize ogi with 20% *P. tuber-regium sclerotium* did not have a statistically significant impact on the vitamin content of the products. However, 30% supplementation gave an increase of 133%, 314% and 233% in thiamine, riboflavin and niacin contents of the final products when compared with the control (table 8). The supplementation also caused significant improvement in the calcium, phosphorus, zinc and magnesium contents of the final products. But it did not improve the sodium and potassium contents of the final products (Table 9). The proximate composition of the products as presented in Table 10 shows lower moisture contents with increased supplementation for all the products. This is particularly good for the shelf-life of the products as lower moisture content discourages the growth of spoilage organisms. The increase in the ash content was also found not to be statistically significant for the 20% sclerotia supplementation. This is understandable considering the fact that maize contains more ash than the sclerotium. The addition of the sclerotia however brought about an increase in the fibre and fat contents of the products when compared to the control. Supplementation of maize-ogi with 20% sclerotia brought about a 36.80% improvement in the fibre content of the ogi while a 30% supplementation gave a 41.72% improvement in fibre content. Also, the 20% and 30% sclerotia supplementation gave a 1.90% and 15.24% improvement in the fat content of the final products in comparison with the control. Furthermore, the addition of 20% and 30% sclerotium to maize-ogi improved the protein content of the final product by 8.97% (M20) and 17.24% (M30) respectively. The limiting amino acids in maize and by extension 'ogi' are lysine, tryptophan and methionine. Supplementing ogi with 20% of the sclerotia of *P. tuber-regium* increased the lysine, tryptophan and methionine contents by 53.55%, 5.01% and 30.77% respectively. In the same vein, the 30% sclerotia supplementation increased the three amino acids by 80.00%, 7.87% and 46.15% (table 11). From these figures, the importance and suitability of the sclerotia of *P. tuber-regium* to supplement ogi is laid bare. Jonathan *et al*., [33] reported that ethanol-soluble sugar and lipid contents of *P. tuber-regium* sclerotia were generally low. This, coupled with the high antioxidant content which it impacted on the ogi supplemented with it as shown in table 12, suggests that people suffering from diabetes, cardiac or weight problems can consume the ogi products.

5. Conclusion

Pleurotus tuber-regium sclerotium is a biological item that can be used to supplement maize ogi for the purpose of nutritive improvement. It does not just have the capacity to improve the protein content of ogi, but also of fat, fibre and vitamins. The problem of protein energy malnutrition (PEM) which is common amongst babies weaned entirely on 'Ogi' in Africa can be solved by supplementing their 'ogi' with the sclerotium

of *P. tuber-regium*.

Competing Interest

We declare that there is no competing interest as far as this work is concerned.

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