Food Research 6 (6) : 13 - 20 (December 2022)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

Effects of pickling treatments and species on the properties of processed mushrooms (*Pleurotus species*)

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Article history:
Received: 3 August 2021
Received in revised form: 5 September 2021
Accepted: 6 January 2022
Available Online: 4 November 2022

Keywords:
Mushroom,
Pleurotus species,
Pickling,
Brine solution

DOI:
https://doi.org/10.26656/fr.2017.6(6).508

Abstract

Mushrooms are important macroscopic fungi, high in vitamins, minerals, proteins, and low in fats, but they are underutilized in developing countries due to seasonal scarcity, unavailability and misconception about fungi. The study focused on processing mushroom *species* by pickling and drying and; evaluating their chemical and physical properties. Four batches of pickled mushrooms were prepared from *Pleurotus pulmonarius* and *Pleurotus ostreatus* by pickling each *species* separately in vinegar and spiced brine solution for 19 hrs, followed by oven drying. The samples were analysed for physical and chemical properties using standard procedures. The research showed that there was insignificant difference (p>0.05) in the protein (19.08-23.87%), fat (0.66-0.92%), crude fibre (19.25-25.89%) and carbohydrates (37.04-42.56%) content among both species and pretreatments. *Pleurotus pulmonarius* showed significantly higher calcium and magnesium content for both treatments than *P. ostreatus*. L* and b* values of the colour parameters showed that the samples were generally light and slightly yellowish (41.12–60.41 and 10.84–17.32 respectively), with *P. pulmonarius* showing a significantly whiter colour for both treatments. Thus, pickling and drying of mushrooms could serve as preservative means for extending their shelf life, and the resulting product could serve as a substitute for meat in soups and stews.

1. Introduction

Mushroom has been described as a macro-fungus, with a distinctive fruiting body that could be hypogenous or epigeous (Wandati *et al.*, 2013). They have been cultivated in large amounts by using lignocelluloses materials such as sawdust, paddy straw and wheat straw (Obodai *et al.*, 2014). They are cultured widely for their nutritional attributes, sensory property and potential industrial utilisation (Nwanze *et al.*, 2006). However, majority of Nigerians, due to mysterious beliefs, seasonal scarcity and unavailability (Kalu *et al.*, 2013) have found it difficult to embrace the use of mushrooms as an alternative source of vitamins and proteins.

Mushrooms could be edible, medicinal or poisonous, depending on their properties and the functions they play. Edible mushrooms are fleshy, with a number of species including *Lentinus edodes*, *Pleurotus, Agaricus, Volvariella, Auricularia polytricha, Coprinus atramentarius, l'olvariella diplosia, Flaninnilbia velutipes, Trcinclla fuciforinis, Pholiota naineko,* (Wani *et al.*, 2010; Kakon *et al.,* 2012). Edible mushrooms have a number of nutritional benefits, including high vitamin contents, lower cholesterol levels, high protein, abundant in amino acids, such as lysine and tryptophan contents (Mshandete and Cuff, 2007; Singh *et al.,* 2016, Enas *et al.,* 2016, Garma and Tasisa, 2018). The content of carbohydrates in mushrooms forms a larger mass of their fruiting bodies, representing 50 to 65% of carbohydrates on a dry weight basis (Girma and Tasisa, 2018). Mushrooms have low-fat content when compared to protein and carbohydrate (Wani *et al*., 2010).

Protein-energy malnutrition is still on the high side in developing countries, especially among children and the vulnerable in society, coupled with poverty. This problem of malnutrition is alarming especially among lower class or poor citizens in developing countries. This has been associated with faulty weaning practices, minimal medical attention, poverty, poor sanitary conditions and endemic childhood infections (Hamidu *et al*., 2003; Emmanuel *et al.*, 2016). Considering the health and nutritional benefits of mushrooms, it will be suitable to embrace their use in diets, especially processed mushrooms for garnishing stews and vegetables. In terms of its availability and economy, the

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eISSN: 2550-2166 / © 2022 The Authors.
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low-income class or underprivileged citizens could embrace this. The elderly or vegetarians in search of a suitable substitute for red meat would also find a diet including mushrooms worth embracing due to its nutritional benefits. As a result of this, there is need to investigate the potentials of this processed mushrooms which is a low-cost nutritious food item. Hence, the processing of dried pickled mushrooms from two species of mushroom and the evaluation of their physical and chemical properties.

2. Materials and methods

2.1 Sources and sample preparation

Freshly harvested *Pleurotus ostreatus* and *Pleurotus pulmonarius* were purchased from Azemor Agribiz Farms, Ibadan, Oyo State, Nigeria. Other ingredients used for the research work were black pepper, salt, sugar, and garlic; these were obtained from an open market in Ibadan, Oyo State. The preparation of the processed mushroom is presented in Figure 1. Four samples of pickled mushrooms were prepared, by pickling each *species* separately in 1% vinegar and spiced brine solution of vinegar-1%, garlic-0.652%, black pepper-0.5%, salt-2% and sugar-1.25%. The dehydrated picked mushroom samples were packaged and kept at low temperatures, while the portions for analysis were ground for further analysis.

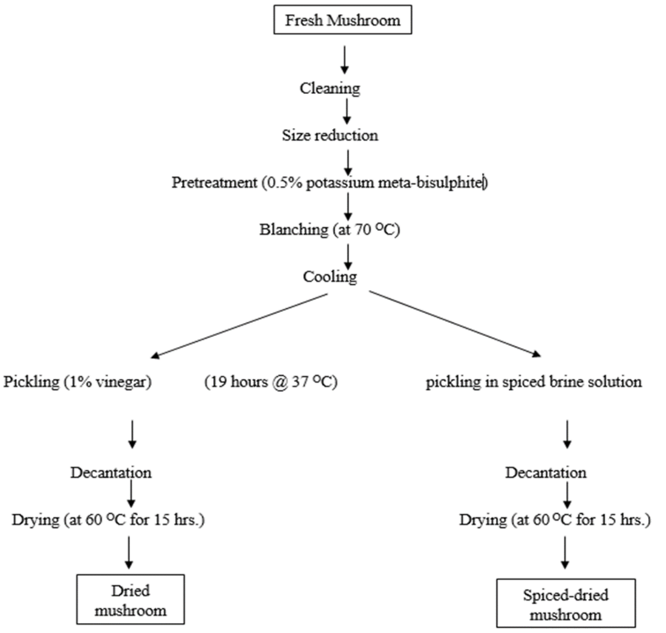

Figure 1. Processing of the pickled and dried mushrooms (Processed mushroom)

2.2 Chemical properties determination

The moisture content, crude fat, crude protein, crude fibre, ash content, pH and titratable acidity (TTA) of the dried pickled mushroom samples were determined using AOAC (2010) method. Carbohydrate contents were determined by differences in protein, crude fat, fibre and moisture content (Low, 2002). The energy values were obtained using the bomb calorimeter model method (Passmore and Eastwood, 1986).

2.3 Anti-nutrients determination

Oxalate was determined by modifying the method of Munro and Basir (1969). Oxalate was extracted with 3 N sulphuric acid, filtered, heated and titrated with potassium permanganate. Phytate content was determined by extraction from the sample with concentrated hydrochloric acid, filtration, addition of distilled water and ammonium thiocyanate solution, followed by titration with standard iron III chloride solution, as described by Russel (1980). The total saponin was determined by spectrophotometry using the method of Hiai *et al.* (1976), with the aid of a calibration curve, and the absorbance was recorded at 544 nm, the determination was carried out by extraction of the sample with 80% methanol, followed by reaction with vanillin reagent and sulphuric acid, before final preparation for measurement.

2.4 Mineral content determination

The mineral contents were determined by AOAC (2010). Calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn) and copper (Cu) contents were analysed by Atomic Absorption Spectrophotometer (AAS); while potassium (K) and sodium (Na) were determined by flame photometer.

2.5 Colour analysis

The Commission International de l'Eclairage (CIE) L*, a*, b* parameters were determined using hunter colorimeter, calibrated with a white tile (Fan *et al.*, 2005). L*- lightness axis (0-100) -0 represents black, while 100 stands for white, a* axis (red-green) –positive values are red while the negative values are green and 0 is neutral; b* axis (yellow-blue)- positive values are yellow, while a negative value is blue and 0 is neutral. Determinations were carried out at 10 different points on the samples.

2.6 Statistical analysis

Data were analysed using SPSS package V20 for analysis of variance (ANOVA) and means separation of triplicate results.

3. Results and discussion

3.1 Chemical properties of processed mushrooms

The pH of the pickles in the solution was checked, and after the 19th hour, it was observed that the pH of all

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Table 1. Acidity of pickling solution and processed mushroom

Samples	pH of pickling solution	pH of pickled and dried sample	TTA (Titratable acidity) of pickled and dried sample
P. pulmonarius in spiced brine solution	2.19[b]	5.14[ab]	0.045[ab]
P. pulmonarius in vinegar	2.54[b]	5.71[a]	0.034[bc]
P. ostreatus in spiced brine solution	2.29[b]	4.42[b]	0.065[a]
P. ostreatus in vinegar	3.09[a]	5.17[ab]	0.018[c]

Means with different superscripts within the same column are significantly different from each other ($P < 0.05$).

the samples dropped below 3.10, which ranged between a pH of 2.19 and 3.09 (Table 1). This is similar to the observation of Liu *et al.* (2016), reporting a drop in pH to below 4.0 after lactic fermentation of Oyster mushrooms for 18 days at 20°C. Hence, the pickling treatment gave a similar result in terms of acidity to fermented mushrooms. The pH of the dried pickled mushroom samples ranged from 4.42 to 5.71, which was within the range of slightly acidic food, and total titratable acidity (TTA) of 0.018 to 0.065%. *P. ostreatus* and *P. pulmonarius* samples pickled in spiced brine solutions had higher acidity content than those of vinegar only as shown by the pH and TTA. These variations in acidity could be a result of the compositions of the pickling solution and their released metabolites. The acidity of the dried pickled mushroom samples is a pointer to its safety and improved durability, as it prevents the growth of undesirable microflora (Steinkraus, 2002; Bello and Akinyele, 2007).

The proximate compositions of the processed mushroom samples are shown in Table 2. The moisture contents of the samples were in the range of 7.60 to 10.69% with significant differences ($p \leq 0.05$) among the samples. This was similar to the moisture content observed for dried mushrooms, 7.3 – 10.94% (Mutukwa, 2014; Ibrahim *et al.*, 2017). Fresh mushroom fruiting bodies possess high moisture content and neutral pH, making them a good media for the growth of microbes (Venturini *et al.*, 2011). The low moisture contents of the processed mushroom fall within the limit of safe moisture content for most food crops (Afolabi, 2014), which is an indication of a longer shelf life than fresh mushrooms, as it prevents microbial growth, hence its availability for use any time needed. The protein contents of the samples varied from 19.08 to 23.87%. Dried *P. pulmonarius* pickled in vinegar had the highest amount of protein (23.87%), followed by *P. ostreatus* pickled in vinegar (20.9%). The protein content of mushrooms on a dry weight basis has been reported to range from 21.42 to 33.71% (Mattila *et al.*, 2002; Simon *et al.*, 2011), having higher digestibility than protein from some plant materials, including soy and peanuts (Chang and Mshigeni, 2001; Siwulski *et al.*, 2011). The report has shown that any product with protein content in the range of 20–50% could be accepted as high protein food, in comparison with milk, fish, meat, and egg (Ukwuru *et al.*, 2018), hence, processed mushroom can be referred to as a high protein food product.

The fat content present in mushrooms is generally low. The content of fat in the processed mushroom of *P. ostreatus* for both treatments was higher (0.79 and 0.92%) than those of *P. pulmonarius* (0.66 and 0.72%), however, there were no significant ($p > 0.05$) differences among both *species* and treatments. This study showed higher fat content than that which was reported by Muthu and Shanmugasundaram (2016) (0.20%). However, higher fat contents were observed by Reis *et al.* (2012) (1.40 and 1.73%) for *P. ostreatus,* and *Lentinula edodes* resp., Simon *et al.* (2011) (3.75%) for *Agaricus bisporus* and Tolera and Abera (2017) (1.94 – 2.42%) for *P. ostreatus*. The low-fat content of mushrooms, which is devoid of cholesterol is an advantage when compared with red meat or processed soybean. The ash content of the samples varied from 3.58 to 14.14% (Table 2), with significant differences among the samples. There has been variations in the range of ash contents reported for mushrooms, 7.6 - 8.8% in *P. ostreatus* (Strmiskova *et al*., 1992; Watanabe *et al.*, 1994), 9.2% in *Agaricus bisporus* (Shah *et al.*, 1997); 8.89 – 12.15% in *P. ostreatus* pretreated and dried differently (Tolera and Abera, 2016). The ash content represents the amount of minerals present in the product. The samples pickled in spiced brine solution had higher ash content than those of vinegar only for both species. This increase could be due to the composition of the spiced brine solution having high mineral contents, including garlic, pepper, sugar and salt, which would have diffused into the mushroom cuts during pickling.

The insoluble portion of the indigestible carbohydrate components known as crude fibre, ranged from 19.25 – 25.89% (Table 2), with significant differences ($p \leq 0.05$) among the samples. Mushrooms have been reported as a valuable source of dietary fibre, lowering cholesterol levels, controlling blood sugar levels and providing support to maintain a healthy weight by Enas *et al.* (2016) and Di-Anibal *et al.* (2015), reporting a range of 20.9-37.4%. The total carbohydrate content ranged from 37.04 to 42.56%, with insignificant differences among the samples, except *P. ostreatus* pickled in vinegar only, having a significantly high carbohydrate content of 42.56%. The food calorific

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Table 2. Proximate composition of the processed (pickled and dried) mushroom

Samples	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude fiber (%)	CHO (%)	Energy (kcal/100 g)
P. pulmonarius in spiced brine solution	7.60^{c}	19.08^{c}	0.66^{b}	14.14^{a}	20.97^{c}	37.54^{b}	316.30
P. pulmonarius in vinegar	8.82^{b}	23.87^{a}	0.72^{ab}	3.58^{c}	25.89^{a}	37.04^{b}	353.68
P. ostreatus in spiced brine solution	10.69^{a}	19.91^{c}	0.79^{ab}	11.64^{b}	19.25^{d}	37.58^{b}	314.07
P. ostreatus in vinegar	9.40^{b}	20.96^{b}	0.92^{a}	4.15^{c}	22.06^{b}	42.56^{a}	350.60

Means with different superscripts within the same column are significantly different from each other ($P < 0.05$).

content of processed mushrooms ranged from 314.07 – 353.68 kcal/100 g (Table 2), which is similar to previous observations for dried mushrooms by Reis *et al.* (2012) (353.5-362.6 kcal) and Mshandete and Cuff, (2007) (350 -400 kg/100 g).

3.2 Anti-nutritional composition of the processed mushroom

The oxalate, phytate and saponin contents of the mushroom samples are shown in Table 3. The oxalate contents showed significant differences ($p \leq 0.05$) among the samples, which ranged from 64.02 to 89.45 mg/100 g. The result showed that pickling in vinegar had significantly lower oxalate content for both *P. pulmonarius* and *P. ostreatus species*. Sharma and Gorai (2018) reported similar oxalate contents for mushrooms, which were from 44 to 89 mg/100 g. The absorption of soluble calcium ions forming insoluble calcium oxalate complex is prevented by a high amount of soluble oxalate in the body, hence the effect of oxalate in the body (Kariuki *et al.,* 2013).

The contents of phytate and saponin in the samples ranged from 0.40-0.54 mg/100 g and 0.21-0.65 mg/100 g respectively (Table 3), with insignificant differences ($p > 0.05$) among the samples. Higher phytate content was observed by Woldegiorgis *et al.* (2015) (31.3-242.8 mg/100 g) for *Agaricus bisporus*. Akindahunsi *et al.* (1999) reported that mushrooms have lower phytate content than green leafy vegetables. Moreover, phytates have the capacity to chelate divalent metal ions forming stable complexes together with mineral ions, and reducing their presence for intestinal uptake (Lopez *et al.*, 2002), hence causing mineral deficiencies. The low level of phytate in mushrooms makes it a good option for combating mineral deficiency.

Food processing operations including fermentation, cooking, milling and autoclaving significantly reduce the levels of anti-nutrients in food materials, including mushrooms (Njoki *et al*., 2014; Woldegiorgis *et al.*, 2015). Reduction of anti-nutrients in the processed mushroom samples would be by leaching of the anti-nutrients into the pickling water, heat treatment during drying of the condiment, as well as other heat treatment that it could be exposed to in the course of preparation.

3.3 Mineral composition of the processed mushroom

The mineral contents of the processed mushroom samples that were evaluated include magnesium (Mg), calcium (Ca), sodium (Na), copper (Cu), potassium (K), iron (Fe) and zinc (Zn), shown in Figure 2. Mushrooms have been observed to play therapeutic roles, which could be linked to the higher mineral components. The Ca, Mg and Na contents of the processed mushroom samples ranged from 121.17 – 156.20 mg/kg, 226.46 – 265.42 mg/kg and 538.58 – 734.26 mg/kg respectively; these are parts of the important macro elements found in mushrooms. Fan *et al.* (2016) reported the significance of calcium in the maintenance and formation of bone and the normal functioning of muscles and nerves in human beings and other vertebrates. The results showed that the treatments of each species had a significant effect on some minerals and no significant effect on others. Cu, Fe, K and Na contents for both *species* pickled in spiced brine solution were higher than the samples treated in vinegar. This higher mineral content of samples pickled in spiced brine than those of vinegar could be because of the diffusion of the components of the spiced brine solution into the mushroom, which included salt, sugar, black pepper and others. The processed mushroom samples were more abundant in potassium (1074-1148 mg/kg) than other mineral components. This is as well an important macro-elements in mushrooms. This observation of high potassium content is close to the report of Bernas *et al.* (2006) and Ijioma *et al.* (2015). The result showed that mushroom is an excellent source of potassium, hence it could form part of 'Dietary

Table 3. Anti-nutritional composition of processed (pickled and dried) mushroom

Samples	Oxalate (mg/100 g)	Phytate (mg/100 g)	Saponin (mg/100 g)
P. pulmonarius in spiced brine solution	89.45±1.4^{a}	0.44±0.02^{a}	0.26±0.127^{a}
P. pulmonarius in vinegar	64.02±2.8^{d}	0.54±0.22^{a}	0.60±0.28^{a}
P. ostreatus in spiced brine solution	75.57±1.40^{b}	0.47±0.12^{a}	0.65±0.021^{a}
P. ostreatus in vinegar	73.59±0.4^{c}	0.40±0.01^{a}	0.21±0.27^{a}

Means with different superscripts within the same column are significantly different from each other ($P < 0.05$).

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Approach to Stop Hypertension' (DASH) as potassium is useful in maintaining fluid balance, normal heart rhythm, muscle as well as nerve functioning (Muthu and Shanmugasundarum, 2016). The Cu, Fe and Zn contents (Figure 2), which are representatives of an element that should be found in trace amounts, were low in contents with copper showing the least amounts (3.51-8.56 mg/kg). Moreover, these elements are essentials, playing important biological roles but could be toxic when levels are elevated excessively (Mallikarjuna *et al.*, 2013).

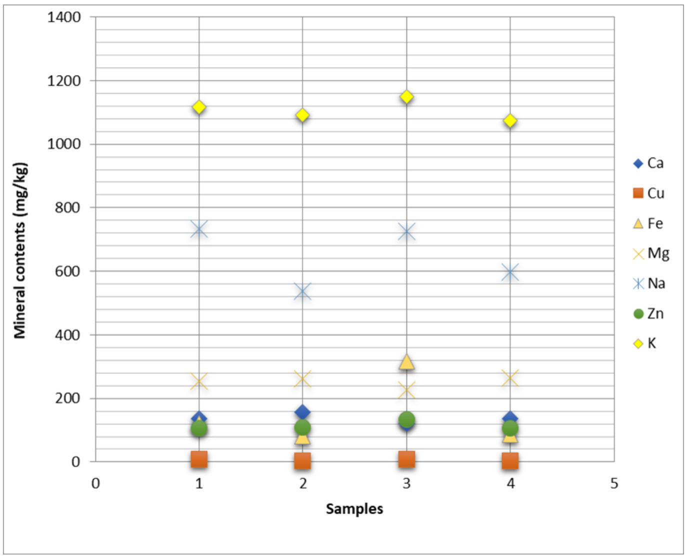

Figure 2. Mineral composition of the processed (pickled and dried) mushroom (mg/kg)
(1 = *P. pulmonarius* in spiced brine solution; 2 = *P. Pulmonarius* in vinegar; 3 = *P. ostreatus* in spiced brine solution; 4 = *P. ostreatus* in vinegar)

3.4 Colour parameters of processed mushroom

Colour is an important quality attribute of food products, used by consumers as an index of quality (Pathare *et al.*, 2013). The use of a colorimeter as an objective means of colour measurement, presents the L*, a* and b* attributes (Table 4). L* parameter of the processed mushroom ranged from 41.11 – 60.41, with significant differences ($p \leq 0.05$) among the samples. The L* axis shows the luminance or lightness component, as 0 is black, and 100 is white. The sample made from *P. pulmonarius* had the lightest colour for both treatments, with the sample treated in spiced brine solution having the highest L* for both *species*. Hence, the differences in *species*, as well as pickling treatment, significantly affected the lightness of the samples.

The a* axis, which indicates the red-green axis (positive values represent red and negative values stands for green and 0 is neutral), ranged from 5.07-6.47. This indicates that the samples are more towards the red axis than green. This can be attributed to the brownish colour of the samples, moving in a positive direction. The b* coordinate of the samples was significantly different ($p \leq 0.05$), which ranged from 10.84 – 17.32, which is the yellow-blue axis. The b* values of *P. pulmonarius* samples showed higher values, that is, it is yellower in colour than *P. ostreatus.* The L* and b* axis showed that the samples treated in spiced brine had higher lightness/yellowness for both *species* than the vinegar treatment, hence the spiced brine solution could be said to be efficient in reducing the rate of browning reactions that occur during processing of mushrooms. The colour parameters of the samples showed that the processed mushroom made from *P. pulmonarius species* and treated in spiced brine is lighter in colour, which could have a high influence on its acceptability.

Table 4. Colour parameters of the processed (pickled and dried) mushroom

Samples	L*	a*	b*
P. pulmonarius in spiced brine solution	60.41±0.08[a]	5.35±0.08[c]	17.32±0.06[a]
P. pulmonarius in vinegar	55.40±0.03[b]	5.65±0.02[b]	16.93±0.03[b]
P. ostreatus in spiced brine solution	49.81±0.01[c]	6.47±0.01[a]	15.96±0.00[c]
P. ostreatus in vinegar	41.11±0.06[d]	5.07±0.05[d]	10.84±0.00[d]

Means with different superscripts within the same column are significantly different from each other ($P < 0.05$).

4. Conclusion

The study showed that processing mushrooms into pickled and dried form could be an alternative way of maximizing the utilization of mushrooms in Nigeria. The two *Pleurotus species* proved to be nutritious. Pickled and dried mushroom stands as a source of protein, minerals and dietary fibre, it has low-fat content, and as well an attractive appearance, that is cream-brownish as shown by the L* and b* values. Thus, the pickled and dried mushrooms could serve as a substitute for meat in soups, and stews preparation, as it is rich in essential nutrients, low in anti-nutrients, and possess attractive colour. Pickling of mushrooms in spiced brine solution and vinegar are simple preservation methods, which is useful in preserving the nutritional quality as well as extending the shelf life. However, the particular pickling solution could be selected based on individuals' preferences or intended use; it could be used as a substitute for meat in soups and stews or as a snack.

Conflict of interest

The authors declare no conflict of interest.

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