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

*Tanimola, A.R., Abai, O.P., Ibitoye, W.O. and Otegbayo, B.O.*

**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*, *Trcinella 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
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.

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
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<sup>b</sup> | 5.14<sup>b</sup> | 0.045<sup>b</sup> |
| *P. pulmonarius* in vinegar | 2.54<sup>b</sup> | 5.71<sup>a</sup> | 0.034<sup>b</sup> |
| *P. ostreatus* in spiced brine solution | 2.29<sup>b</sup> | 4.42<sup>b</sup> | 0.065<sup>a</sup> |
| *P. ostreatus* in vinegar | 3.09<sup>a</sup> | 5.17<sup>b</sup> | 0.014<sup>c</sup> |

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

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 Shannugasundaram (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 Toler 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 (Toler 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 ≤ 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
combating mineral deficiency. The level of phytate in mushrooms makes it a good option for stable complexes together with mineral ions, and soluble calcium ions forming insoluble calcium oxalate complex is prevented by a high amount of soluble oxalate 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 ≤ 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 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^b         | 37.54^b | 316.30             |
| P. pulmonarius in vinegar        | 8.82^b       | 23.87^a     | 0.72^ab    | 3.58^e      | 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^e      | 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).

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).
Approach to Stop Hypertension’ (DASH) as potassium is useful in maintaining fluid balance, normal heart rhythm, muscle as well as nerve functioning (Muthu and Shanmugasundaram, 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 ≤ 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 having the highest L* for both species (Figure 3). 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 ≤ 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.

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.

References

Afolabi, I.S. (2014). Moisture migration and bulk nutrients interaction in a drying food system: A

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).
Fan, P., Chen, N. and Xue, S. (2016). Calcium intake, calcium homeostasis and health. *Food Science and Human Wellness*, 5(1), 8-16. https://doi.org/10.1016/j.fshw.2016.01.001

Girma and Tasisa T. (2018). Application of Mushroom as Food and Medicine. *Advances in Biotechnology and Microbiology*, 11(4), 555817. https://doi.org/10.19080/AIBM.2018.11.555817

Hamidu, J.L., Salami, H.A., Ekanem, A.U. and Hamman, L. (2003). Prevalence of Protein Energy Malnutrition in Maiduguri, Nigeria. *African Journal of Biomedical Research*, 6(3), 123 – 127. https://doi.org/10.4314/ajbr.v6i3.54039

Hiai, S., Oura, H. and Nakajima, T. (1976). Color reaction of some sapogenins and saponins with vanillin and sulfuric acid. *Planta Medica*, 29(2), 116-122. https://doi.org/10.1055/s-0028-1097639

Ibrahim T.A., Adaramola-Ajibola K.M., Adesuyi A.T, Olamrewaju S.O. and Akinro E.B. (2017). Effect of Pre-Treatments and Drying Methods on the Chemical Quality and Microbial Density of Wild Edible Oyster Mushroom. *Archive of Food and Nutritional Science*, 1, 39-44. https://doi.org/10.29328/journal.afns.1001007

Kakon A.J., Choudhury B.K. and Saha S. (2012). Mushroom is an Ideal Food Supplement Mushroom. Journal of Dhaka National Medical College and Hospital, 18, 58-62. https://doi.org/10.3329/jdnmch.v18i1.12243

Kalu, I.G., Nwachukwu, C.U. and Evans-Kemka, C.I. (2013). Problems facing Mushroom availability and consumption in Owerri Municipal Council of Imo State Nigeria. *Journal of Biology, Agriculture and Healthcare*, 3(8), 113-117.

Kariuki, S.W., Sila, D.N. and Kenji, G.M. (2013). Nutritional profile of amaranth grain varieties grown in Kenya. *Journal of Food Science, Agriculture and Food*, 17, 19-24.

Liu, Y., Xie, X.-x., Ibrahim, S.A., Khaskheli, S.G., Yang, H., Wang, Y.F. and Huang, W. (2016). Characterization of Lactobacillus pentosus as a starter culture for the fermentation of edible oyster mushrooms (*Pleurotus* spp.). *LWT - Food Science and Technology*, 68, 21–26. https://doi.org/10.1016/j.lwt.2015.12.008

Lopez, W.H., Leenhardt, F., Coudray, C. and Remesy, C. (2002). Minerals and phytic acid interaction: is it a real problem for human nutrition. *International Journal of Food Science and Technology*, 37(7), 727-739. https://doi.org/10.1046/j.1365-2621.2002.00618.x

Low, N.H. (2002). Carbohydrate Analysis. In Nielsen, S.S. (Ed.) *Introduction to the Chemical Analysis of Foods*. New Delhi, India: CBS Publishers and distributors.
Mallikarjuna, S.E., Ranjini, A., Haware, D.J., Vijayalakshmi, M.R., Shashirekha, M.N. and Rajarathnam M.S. (2013). Mineral Composition of Four Edible Mushrooms. *Journal of Chemistry*, 2013, 805284. http://dx.doi.org/10.1155/2013/805284

Mattila, P., Lampi, A.M., Ronkainen, R., Toivo, J. and Piironen, V. (2002). Sterol and vitamin D2 contents in some wild and cultivated mushrooms. *Food Chemistry*, 76(3), 293–298. https://doi.org/10.1016/S03088146(01)00275-8

Mshandete, A.M. and Cuff, J. (2007). Proximate and nutrient composition of three types of indigenous edible wild mushrooms grown in Tanzania and their utilization prospects. *African Journal of Agricultural Nutrition and Development*, 7(6), 1-6. https://doi.org/10.18697/ajfand.17.2615

Munro, A.B. and Basir, O. (1969). Oxalate in Nigeria vegetables. *West Africa Journal of Biology and Applied Chemistry*, 12(1), 14-18

Muthu, N. and Shannugasundaram, K. (2016). Proximate and mineral compositions of edible mushroom *Agrocybe aegerita*. *Journal of Pharmacognosy and Phytochemistry*, 5(1), 116-119

Mutukwa I. (2014). Drying and pretreatments affect the nutritional and sensory quality of oyster mushrooms. North Dakota, USA: University of Agriculture and Applied Science. PhD thesis.

Njoki, J.W., Silva, D.N. and Onyango, A.N. (2014). Impact of Processing Techniques on Nutrient and Anti-Nutrient Content of Grain Amaranth (*A. albus*). *Food Science and Quality Management*, 25, 10–17

Nwanze P.I., Jatoi W., Oranusi S. and Josiah S.J. (2006). Proximate analysis of *Lentinus squanosulus* (mont.) singer and *Psallyrella atroumbonata* pegler. *African Journal of Biotechnology*, 5(4), 366-368.

Obodai M., Owwusu E., Schiwenger G.O., Asante I.K. and Dzomeku M. (2014). Phytochemical and Mineral Analysis of 12 Cultivated Oyster Mushrooms (*Pleurotus Species*). *Advances in Life Science and Technology*, 26, 35-42

Passmore, R. and Eastwood, W.A. (1986). Human Nutrition and Dietetics. Churchill, United Kingdom: English Language Book Society.

Pathare, P.B., Opara, U.L. and Al-Said, F.A. (2013). Colour Measurement and Analysis in Fresh and Processed Foods: A Review. *Food and Bioprocess Technology*, 6, 36-60 https://doi.org/10.1007/s11947-012-0867-9

Reis, F.S., Barros, L., Martins, A. and Ferreira I.C.F.R. (2012). Chemical composition and nutritional value of the most widely appreciated cultivated mushrooms: An inter-species comparative study. *Food and Chemical Toxicology*, 50(2), 191–197. https://doi.org/10.1016/j.fct.2011.10.056

Russel, H.S. (1980). Indian New England before the May Flower. 1st ed. London, United Kingdom: University Press of New England.

Shah, H., Iqtiidar, A.K. and Shagufta, J. (1997). Nutritional composition and protein quality of *Pleurotus* mushroom. *Sarhad Journal of Agriculture*, 13(6), 621 – 626.

Sharma, R. and Gorai, B. (2018). Estimation of Soluble, Insoluble and Total Oxalate Contents in Common Edible Mushrooms of West Bengal, India. *International Journal of Current Microbiology and Applied Sciences*, 7(7), 264-268. https://doi.org/10.20546/ijcmas.2018.707.031

Simon, R.R., Phillips, K.M., Horst, R.L. and Munro, I.C. (2011). Vitamin D mushrooms: Comparison of the composition of button mushrooms (*Agaricus bisporus*) treated postharvest with UVB light or sunlight. *Journal of Agricultural and Food Chemistry*, 59(16), 8724–8732. https://doi.org/10.1021/jf201255b

Singh J., Sindhu, S.C. and Sindhu, A. (2016). Development and evaluation of value-added pickle from dehydrated shiitake (*Lentinus edodes*) mushroom. India *International Journal of Food Science and Nutrition*, 1(1), 24-26

Siwulski, M., Jasińska, A., Sobieralski, K. and Sas-Golak, I. (2011). Comparison of chemical composition of fruiting bodies of some edible mushrooms cultivated on sawdust. *Ecological Chemistry and Engineering*, 18(1), 89–96.

Steinkraus, K.H. (2002). Fermentations in world food processing. *Comprehensive Reviews in Food Science and Food Safety*, 1(1), 23–32. https://doi.org/10.1111/j.1541-4337.2002.tb00004.x

Strmiskova, G., Strmiska, F. and Dubravicky, J. (1992). Mineral composition of Oyster mushroom. *Nahrung*, 36(2), 210 – 212. https://doi.org/10.1002/food.19920360218

Tolera, K.D. and Abera, S. (2017). Nutritional quality of Oyster Mushroom (*Pleurotus ostreatus*) as affected by osmotic pretreatments and drying method. *Food Science and Nutrition*, 5(5), 989–996. https://doi.org/10.1002/fsn3.484

Ukwuru, M.U., Muritala, A. and Eze, L.U. (2018). Edible and non-edible wide mushroom; Nutrition, Toxicity and Strategy for Recognition. *Journal of Chemical Nutrition and Metabolism*, 2(2), 9.

Venturini, M.E., Reyes, J.E., Rivera, C.S., Oria, R. and Blanco, D. (2011). Microbiological quality and
safety of fresh cultivated and wild mushrooms commercialized in Spain. Food Microbiology, 28(8), 1492–1498. https://doi.org/10.1016/j.fm.2011.08.007

Wandati, T.W., Kenji, G.M. and Ongusol J.M. (2013). Phytochemicals in Edible Wild Mushrooms from Selected Areas in Kenya Journal of Food Research, 2(3), 137-144. https://doi.org/10.5539/jfr.v2n3p137

Wani, B.A., Bodha, R.H. and Wani, A.H. (2010). Nutritional and medicinal importance of mushrooms Journal of Medicinal Plants Research, 4(24), 2598-2604.

Watanabe, T., Tsuchihasi, N., Takai, Y., Tanaka, K. and Suzuki, A. (1994). Effects of ozone exposure during cultivation of oyster mushroom (Pleurotus ostreatus) on chemical components of the fruit bodies. Journal of the Japanese Society for Food Science and Technology, 41(10), 705 – 708. https://doi.org/10.3136/nskkk1962.41.705

Woldegiorgis, A.Z., Abate, D., Haki, G.D. and Ziegler, G.R. (2015). Major, Minor and Toxic Minerals and Anti-Nutrients Composition in Edible Mushrooms Collected from Ethiopia. Journal of Food Processing Technology, 6(3), 1000430. https://doi.org/10.4172/2157-7110.1000430