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Influence of varying preservation methods on the shelf life and proximate composition of *Pleurotus plumonarius* (Fr) Quel cultivated on *Andropogon gayanus* substrate

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Abstract

The objective of the work was to evaluate the influence of preservation methods on the storability and proximate composition of *Pleurotus pulmonarius*. The experiment was laid out in a completely randomized design (CRD) with three replicates. Freshly harvested mushrooms grown on *Andropogon gayanus* substrate and analyzed for its proximate composition were divided into four portions: sun dried (SD), oven dried (OV), blanched and unblanched stored directly in citric acid solution at varying concentrations (conc.) (0.0%, 0.1%, 0.3% and 0.5%). The microbial load count of the preserved samples and sensory evaluation carried out were significant ($P<0.05$) with sun and oven dried samples most preserved followed by blanched samples stored in citric acid solutions, with 0.5% conc. The proximate results showed that the protein, fat, and ash contents of mushroom preserved in citric acid solution decreased while sun and oven dried samples increased significantly with increase in fibre and carbohydrate. The result of the sensory evaluation on colour, texture and flavour showed that blanched sample stored in 0.5% citric acid solution was most preferred for colour, odour and texture.

Keywords: Citric acid solution, Mushroom, Proximate composition, Storability

Introduction

Some mushrooms have been found to provide a rich addition to the diet of man in the form of protein, carbohydrate, mineral, vitamins and enzymes (Okwulehie and Nosike, 2015) and are widely appreciated for their unique taste and flavour. Their medicinal (Ferreira et al., 2010) properties, such as: anti-inflammatory, anti-diabetic, anti-bacterial and anti-tumor which is attributed to the presence of bioactive metabolites (e.g. phenolic compounds, terpenes, steroids and polysaccharides) have also been observed. In particular, edible mushrooms can be a source of nutraceuticals with important antioxidant properties, which can positively influence the oxidative stress in cells and related diseases (Ferreira et at., 2009). Mushroom proteins are comparatively rich in the amino acids aspartic acid (9.10%–12.1%), arginine (3.70%–13.9%) and glutamic acid (12.6%–24.0%) but deficient in sulfur-containing amino acids, such as: cysteine and methionine (Cheung, 2010). Studies on edible mushroom have resurfaced as world nutrition is observed as shifting from processed to natural foods. This has almost led to warning for people to stay away from non fresh foods (Ihediohanma et al., 2014) due to uncertainty surrounding their safety. Mushroom production is a lucrative and profitable business especially for low income rural households and this industry is providing full or part time employment to both rural and urban poor and marginal farmers in many developing countries (Ferchak and

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Croucher, 2001). Currently, mushroom cultivation has been observed in more than 100 countries of the world with estimated total production of over 12 million metric tons (Suman and Sharma, 2007). It is considered one of the most important food items since ancient time and its consumption is increasing over the period for its significant role in human health, nutrition and disease management (Uddin, et al., 2011). The market value of dietary supplements from mushrooms is rapidly growing and estimated over U.S. $15 billion (Wasser, 2012; Panagiota and Philippoussis, 2015).

Shelf life is the length of time during which all of a commodity essential properties still remain acceptable for use, consumption or sale (Akram and Kwon, 2010). Mushrooms at ambient temperatures (< 22°C) have a short shelf-life of 1–3 days (Burton and Twyning, 1989), at 15°C their shelf-life is 2–3 days (Gormley 1981), whereas in the tropics they count only 24 hours (Wakchaure 2011) being one of the most perishable food products and tend to lose quality immediately after harvest. The shelf life is reduced due to post-harvest changes such as: browning, cap opening, stipe elongation, cap diameter increase, weight loss and texture damage, related to their high respiration rate and moisture, relatively high protein content, and lack of physical protection to avoid water loss or microbial attack (Fernandes et al., 2012c). This has resulted to a serious decrease in the commercial, medicinal and nutritional value of edible mushrooms. Therefore, mushrooms are mainly used in the processed form (Jaworska and Bernás, 2009). Extending shelf-life is an imperative factor to increase the profitability and availability of any food product, since it offers the possibility of developing markets at a greater distance (Akram and Kwon, 2010) however, it is needful that the applied technology does not act itself as a source of chemical modifications.

Furthermore, as earlier stated, the fruit-bodies of mushrooms are highly perishable and most of the fruit-bodies produced are lost due to moisture loss, colour changes and of course poor preservation methods. Various mushroom preservation methods including blanching, freezing (Lyophilization and cryopreservation), steaming, oil or butter sautéing, drying, canning (sterilization), pickling and salting have been reported by different researchers (Chang & Miles, 2004; Uzunova-Doneva and Donev, 2005; Abatenh and Gizaw, 2018). However, each has shown at some point deficiency in performance and some, cost ineffective. For instance, drying often toughens or changes mushroom texture as well as resulting to the lost of colour, volatile flavours and aromas (Kaur et al., 2011; Rahart, 2017; Abatenh and Gizaw, 2018). Furthermore, it has been reported that mushrooms stored by blanching require further treatment like crisping and frying, otherwise quality is reduced over a short time, steaming can be somewhat more time-consuming and does not clean dirt, sand, and grit (Rahart, 2017). Canning was reported (Panagiota and Philippoussis, 2015) to be expensive and sometimes finicky equipment is necessary, filled with complicated processes, and requires very strict adherence to methods, procedures, and techniques. This is not a method to where one can cut corners. Under pickling, recipes must be proven and techniques adhered to rigidly. It is not a good medium for experimentation, as improper acid balance could lead to botulism or other serious food poisonings etc. The anti-bacterial and anti-browning properties of some chemical compounds such as: ascorbic acid, citric acid, hydrogen peroxide, sodium erythorbate, chlorine dioxide, sodium disoascorbate monohydrate, sodium D, L-isoascorbate and their derivatives along with hydrocolloid-based substances against fruit and vegetable spoilage have been reported (Cliffe-Byrnes and O'berrne, 2008; Simon and Gonzalez-Fandos, 2009). This could be an effective mushroom shelf life elongation method provided the right dosage and combination is maintained.

Therefore, determining the best and effective approach to store *Pleurotus plumonarius* sp. fresh, which is a highly relished mushroom species in Nigeria and sub-Saharan Africa, raises a concern to researchers. Improving their shelf life and quality characteristics will enhance marketability and value addition on food chain. Similarly, evolving preservation methods that are cheap and reliable especially to poor resource farmers is imperative in order to achieve food sustainability, which forms the basis for storability methods chosen in this trial. Hence, this study was carried out to investigate different preservation methods for fragile mushrooms so as to know the most effective method with retained nutritional values of the stored mushrooms when compared to the fresh ones.

Materials and Methods

Spawn mother culture was obtained from the Department of Biotechnology, Federal Institute of Industrial Research Oshodi (FIIRO), Lagos State, Nigeria and multiplied (bulked up) in the Department of Plant Science and Biotechnology, Michael Okpara University of Agriculture, Umudike.

Processes of Production of Mushroom Fruit-Bodies

The spawn multiplication was done following the method of Okwulehie and Okwujiako (2008). Sorghum grains were washed, parboiled and then allowed to drain completely. About 100g of the grains were thoroughly mixed with 5g of calcium carbonates and 5g of calcium sulphate for pH optimization and prevention of clumping respectively. The grains were autoclaved at 121°C for 45 minutes and then allowed to cool. The sterile sorghum were inoculated with the mother spawn and then incubated in the dark at room temperature for 2 weeks for mycelia running (ramification) (Baysal et al., 2003).

The substrate, which is straw of *Andropogon gayanus* was chopped into pieces of about 1-3cm average lengths and soaked 48hrs in tap water according to the method of Sharma et al. (2003). 1kg of completely drained prepared A. gayanus straw was packed into 2.5litres transparent plastic bucket perforated from bottom to the top. Buckets containing the substrates were pasteurized for one hour at 80°C in a gas-heated drum and allowed to cool overnight as suggested by Okwulehie and Nosike, (2015).

During inoculation, pasteurized substrates were thoroughly mixed with 10g of the spawn in transparent plastic buckets. The buckets containing inoculated substrates were placed on wooden racks and covered with black polythene sheets to

avoid contamination and to provide dark environment needed for vegetative growth of mycelia during incubation as recommended by Okwulehie et al. (2014).

During spawn run, cropping room was flooded with tap water to optimize relative humidity between 75-80% and temperature at 27±2^{O}C. Inoculated substrates were regularly checked against contamination until substrates were fully colonized by mycelia. When substrates were fully colonized by mycelia, covering sheaths were removed to allow for ample supply of oxygen and light required for primodia initiation. Air humidity was increased by spray-watering the substrates daily and was discontinued as soon as fruit bodies were formed according to Mwita et al. (2011).

Harvesting was done at maturity by hand-picking. The fruit-bodies which appeared mostly in bunches were picked by the stipe at the base and twisted gently to avoid injury. The harvested fruit-bodies were washed thoroughly under running tap water to reduce microbial load and adhering soil particles based on Melese and Workneh, (2015) recommendation.

Experimental design

The experiment was carried out in a completely randomized design (CRD). The set up was made up of ten (10) treatments with three (3) replicate. This gave a total of thirty (30) experimental units for one (1) week and a combined total of one hundred and twenty (120) experimental units for four (4) weeks.

Preservation methods

The prepared fruit-bodies were preserved using the following methods:

Chemical preservation

Citric acid was made into the concentration of 0.0%, 0.1%, 0.3% and 0.5% by diluting in the corresponding quantity of water. Two grams (2g) each of fresh fruit-bodies of P. pulmonarius (blanched and unblanched) were put in eight 473 ml bottles containing different concentration of citric acid according to the modified method of Ifeoluwa et al. (2015).

Drying

15g of the fruit-bodies were put in brown envelopes and oven dried at 50^{o}C for 4 hours, and then wrapped with aluminium foil to avoid moisture absorption. Another 15g of fruit-bodies were sun-dried in saucer pans for a period of 3 days.

Determination of mushroom shelf life

Shelf life was determined by running microbial test at 1week interval for all the mushroom samples during the experiment. This was done for 1 month as follows:

Nutrient agar (NA) and Sabourand Dextrose agar (SDA) were first prepared by measuring 39g of SDA and 28g of NA into a flask containing 1000ml of distilled water each, they were uniformly mixed by shaking and corked using cotton wool and aluminium foil. This was autoclaved at 121^{o}C for 45 minutes. After autoclaving the SDA and NA mixtures were poured into various well labelled petri dishes to cool and solidify.

Each of the preserved samples was diluted in ten-fold serial dilution technique as described by Joanne et al. (2010). Test tubes were set up in a rack and filled with 9ml of distilled water labelled as stock 10^{-1}, 10^{-2}, 10^{-3}, up to 10^{-12} respectively. An aliquot (1ml) was added using a pipette and transferred from the sample tube into the one labelled 10^{-1} and carefully homogenized. Similarly 1ml was drawn up from the 10^{-1} tube and transferred to the 10^{-2} tube. This dilution continued up to the last test tube labelled 10^{-4} and 10^{-5} from which 1ml was discarded. This procedure was carried out for all the samples except for the samples in solid forms where 1g was soaked in 10ml of sterile distilled water, properly homogenized and diluted in the above dilution technique.

Dilutions from 10^{-4} and 10^{-5} tube were inoculated into freshly prepared Nutrient agar (NA) and Sabourand Dextrose agar (SDA) plates for bacterial and fungal counts, respectively. The spread plate method of inoculation as described by Prescott et al. (2008) was used where 0.1ml of the dilutions (10^{-4} and 10^{-5}) were placed on the various agar plates and evenly spread over the entire plate using a flame sterilized glass rod. The inoculated plates were incubated at 35^{o}C for 24hrs and 72hrs for bacteria and fungi, respectively.

After incubation, the number of resulting colonies was counted using a colony counter and total microbial load (expressed as cfu/ml or cfu/g) was estimated using:

Microbial load = Reciprocal of dilution factor x Number of colonies counted

Dilution Factor (DF) = Initial dilution x Subsequent dilution x Volume of inoculums.

Where,

Cfu/ml = Colony forming unit per millilitre.

Cfu/g = Colony forming unit per gram.

Proximate analysis

Proximate analysis was carried out on each of the 10 samples. The protein, ash, fat, moisture and crude fibres were determined by the method of AOAC (2005). Carbohydrate content was calculated by difference as the nitrogen free extract (NFE), a method separately described by James (1995). Nitrogen free extract estimates non-fibrous carbohydrate such as sugars and starches. This was calculated by:

% NFE = 100 % - (a + b + c + d) %

Where,

a = protein, b = fat, c = fibre, d = ash.

Descriptive sensory evaluation was used in the screening of preserved mushroom based on their sensory quality characteristics. A questionnaire was administered to assess these attributes using a 9 point hedonic scale. A total of 10 panellists were involved in the sensory evaluation using the 9 point hedonic scales. The preserved mushroom samples were presented for panellist to evaluate the colour, texture, flavour and overall acceptability of the samples. All panellists were allowed to evaluate the samples for each quality feature using rating scale. All panellists were instructed to make their own individual assessments according to the evaluation criteria provided for each samples on the basis of colour, texture, flavour and overall acceptability. Finally, the scores of all judges were added and divided by the number of judges to find the final mean score.

Statistical analysis

The statistical package that was used in this experiment

is SPSS. Data obtained during the experiment were analyzed using ANOVA while the means were separated using Duncan New Multiple Range Test (Steel and Torrie, 1980).

Results and Discussion

It is important for a food product to conform with the microbiological criteria in order to certify that it is of good quality and will not pose any risk to the health of consumers. Mushrooms deteriorate easily due to high rate of respiration, and this shortens their shelf life (Valerie and David, 2008), hence, unsafe and unavailable for consumption. The role played by microbial populations in the postharvest quality of mushrooms has been reported (Soler-Rivas et al., 1999).

From the present result, the total heterophilic bacteria load count (Table 1) showed that bacteria load of the treated samples increased during storage irrespective of the treatments. The values obtained for the dried samples (SD and OV) were significantly different from blanched and unblanched samples preserved with citric acid. The total heterophilic bacteria count in week one ranged from 1.10 x 10^4 in SD to 3.00 x 10^5 in BC and UBC (control samples). The lower bacteria count on the dried samples could be attributed to the low moisture content which discouraged microbial activities (Okhuoya, 2011). Similar observation on Indian goose berry powder during storage was reported by Pareek and Kaushik (2012). The values obtained for the unblanched samples after one week showed significant difference ($P<0.05$) and ranged from 1.58 x 10^5 in UB0.5 to 3.00 x 10^5 in UBC. This steady decrease in bacteria load count observed in the samples preserved in higher concentration of citric acid solution confirms the antibacterial property of citric acid. Zhang et al. (2006) had reported a similar result in sweet potato. The same scenario was also observed for the blanched samples. The lower microbial load count value obtained in week one for blanched samples at 0.5 citric acid storage when compared to unblanched samples at the same concentration of citric acid showed significant difference ($P<0.05$), this ranged from 1.5 x 10^4 in B0.5 to 1.58 x 10^5 in UB0.5. This may be due to the fact that boiling temperature could have killed some of the microorganism during blanching. Similar result was reported by Fana et al. (2015) on orange fleshed sweet potato. Week 2 and week 3 followed the same trend.

Table 1. Total heterophilic bacterial load count of treated *Pleurotus pulmonarius* during storage

Treatment	Week 1	Week 2	Week 3	Week 4
SD	$1.1^{h}x10^{4}$	$1.5^{d}x10^{6}$	$7.8^{f}x10^{8}$	$>10^{9}$
OV	$6.15^{f}x10^{4}$	$4.65^{cd}x10^{6}$	$9.6^{e}x10^{8}$	$>10^{9}$
UB0.5	$1.58^{e}x10^{5}$	$4.5^{cd}x10^{6}$	$1.30^{d}x10^{9}$	$>10^{9}$
UB0.3	$2.09^{c}x10^{5}$	$1.10^{b}x10^{7}$	$1.83^{c}x10^{8}$	$>10^{9}$
UB0.1	$2.57^{b}x10^{5}$	$1.31^{b}x10^{7}$	$2.28^{b}x10^{9}$	$>10^{9}$
UBC	$3.00^{a}x10^{5}$	$2.11^{a}x10^{7}$	$2.90^{a}x10^{9}$	$>10^{9}$
B0.5	$1.5^{h}x10^{4}$	$2.7^{cd}x10^{6}$	$5.2^{g}x10^{8}$	$>10^{9}$
B0.3	$3.3^{g}x10^{4}$	$6.4^{c}x10^{6}$	$1.08^{e}x10^{9}$	$>10^{9}$
B0.1	$1.81^{d}x10^{5}$	$1.13^{b}x10^{7}$	$1.92^{c}x10^{9}$	$>10^{9}$
BC	$3.00^{a}x10^{5}$	$1.88^{a}x10^{7}$	$2.30^{b}x10^{9}$	$>10^{9}$

SD = sun dried, OV = oven dried, UB0.5 = unblanched at 0.5 conc., UB0.3 = unblanched at 0.3 conc., UB0.1 = unblanched at 0.1 conc., UBC = unblanched control, B0.5 = blanched at 0.5 conc., B0.3 = blanched at 0.3 conc., B0.1 = blanched at 0.1 conc., BC = blanched control. Values are mean of triplicate observation, values with different superscripts on the same column are significantly different ($P<0.05$)

Table 2. Total fungal load count on treated Pleurotus pulmonarius

Treatment	Week 1	Week 2	Week 3	Week 4
SD	$0.4^{i}x10^{4}$	$0.8^{h}x10^{6}$	$0.6^{g}x10^{8}$	$>10^{9}$
OV	$2.4^{h}x10^{4}$	$3.5^{g}x10^{6}$	$1.7^{f}x10^{8}$	$>10^{9}$
UB0.5	$8.1^{e}x10^{4}$	$6.4^{e}x10^{6}$	$4.4^{e}x10^{8}$	$>10^{9}$
UB0.3	$1.23^{e}x10^{5}$	$8.4^{d}x10^{6}$	$8.6^{d}x10^{8}$	$>10^{9}$
UB0.1	$1.82^{a}x10^{5}$	$1.15^{c}x10^{7}$	$1.10^{e}x10^{9}$	$>10^{9}$
UBC	$1.07^{d}x10^{5}$	$1.62^{b}x10^{7}$	$2.11^{a}x10^{9}$	$>10^{9}$
B0.5	$0.5^{i}x10^{4}$	$2.7^{g}x10^{6}$	$0.95^{fg}x10^{8}$	$>10^{9}$
B0.3	$3.9^{g}x10^{4}$	$5.1^{f}x10^{6}$	$3.8^{e}x10^{8}$	$>10^{9}$
B0.1	$7.0^{f}x10^{4}$	$8.0^{d}x10^{6}$	$7.9^{d}x10^{8}$	$>10^{9}$
BC	$1.52^{b}x10^{5}$	$2.50^{a}x10^{7}$	$1.92^{b}x10^{9}$	$>10^{9}$

SD = sun dried, OV = oven dried, UB0.5 = unblanched at 0.5 conc., UB0.3 = unblanched at 0.3 conc., UB0.1 = unblanched at 0.1 conc., UBC = unblanched control, B0.5 = blanched at 0.5 conc., B0.3 = blanched at 0.3 conc., B0.1 = blanched at 0.1 conc., BC = blanched control. Values are mean of triplicate observation, values with different superscript on the same column are significantly different ($P<0.05$)

The result for total fungal load count (Table 2) of the samples were significantly different (P<0.05). Similar observation to the bacteria load count was recorded for total fungi load count. Values obtained ranged from 0.40 x 10^4 in SD to 1.52 x 10^5 in BC for week one, 0.80 x 10^6 in SD to 2.50 x 10^7 in BC for week two, while in the third week it ranged from 0.60 x 10^8 in SD to 2.11 x 10^9 in UBC. The lower load count on the dried samples when compared to the other samples could be attributed to the low moisture content which discouraged microbial activities (Okhuoya, 2011). Pareek and kaushik (2012) reported similar observation on Indian goose berry powder. As with the result for bacteria load count, increase in the concentration of preservative used caused a sequential decrease in the load count of the samples. Blanched samples containing preservatives at different concentration also had lower load count compared to the unblanched samples.

The result obtained from the proximate composition of the fresh P. pulmonarius showed that the mushroom is a rich source of protein and fibre (Table 3). The lower value obtained for ash, fat and protein when compared to the results reported by some authors like Ayodele and Okhuoya (2009); Kuforiji et al. (2000) and Aletor (1995) could be attributed to the fact that the mushroom in this study was analyzed on fresh matter basis. However the protein and fibre content in this fresh mushroom was higher than that reported by Okwulehie et al. (2014) for mushroom, Hernandez et al. (2008) for tomato and Amandikwa (2012) for cocoyam. The value for the moisture content compared similarly to the result reported by Okwulehie et al. (2014) on mushroom. The high protein content of P. pulmonarius will help to enhance the protein level of food cooked with it thereby reducing the over dependence on meat and fish which are comparatively expensive for the low income earners where majority of our farmers in the tropics belong. The higher fibre contents is an added advantage as fibre have been reported to have the ability to lower the serum cholesterol level, heart disease, hypertension, constipation, diabetes and cancer (Ishida et al., 2000). The high moisture content is of disadvantage especially to storage, as high moisture content encourages microbial activities which bring about food degradation and spoilage (Okhuoya, 2011). The low carbohydrate content is of great advantage to diabetic patients that require low carbohydrate content food.

Table 3. Proximate composition of freshly harvested *Pleurotus pulmonarius*

Nutrient composition	Percentage (%)
Crude protein	10.18±0.46
Fat	2.23±0.04
Ash	2.50±0.00
Crude fibre	6.30±0.14
Moisture	72.63±0.11
Carbohydrate	6.18±0.67

Table 4 shows the proximate composition of the treated mushroom after one week of storage. The result showed significant difference in all the proximate parameters. However, the values obtained for the dried samples (OV and SD) were much higher when compared to blanched and unblanched samples irrespective of the concentration of the citric acid, for crude protein, fat, ash, crude fibre and carbohydrate. This might be as a result of moisture loss which in turn caused the nutrients to concentrate on the dried samples. Muyanja et al. (2012) reported similar observation on oyster mushroom. The values obtained for protein at 0.5 citric acid concentration ranged from 9.20 for unblanched to 9.65 for blanched samples which showed non significant (P>0.05) difference. Similar result was reported by Muyanja et al. (2012). The decrease in protein content of the blanched and unblanched samples at different concentration of the preserving solution suggests the

Table 4. Proximate composition of *Pleurotus pulmonarius* after one week of storage

Treatment	Crude protein	Fat	Ash	Crude fibre	Moisture	Carbohydrates
SD	29.40^{a}±0.00	6.80^{b}±0.06	11.25^{a}±0.07	14.43^{b}±0.11	9.70^{d}±0.07	28.43^{b}±0.17
OV	28.30^{b}±0.49	7.15^{a}±0.07	10.50^{b}±0.14	15.35^{a}±0.07	8.45^{e}±0.07	30.25^{a}±0.42
UB0.5	9.65^{c}±0.14	1.41^{c}±0.01	2.25^{c}±0.07	7.25^{d}±0.07	73.13^{c}±0.11	6.32^{f}±0.16
UB0.3	8.85^{d}±0.35	1.33^{d}±0.04	2.08^{cd}±0.11	7.00^{e}±0.00	73.28^{bc}±0.04	7.48^{def}±0.25
UB0.1	8.25^{e}±0.0	1.25^{def}±0.00	1.83^{ef}±0.04	6.73^{f}±0.04	73.62^{bc}±0.05	8.33^{cd}±0.04
UBC	7.40^{f}±0.14	$1.20f^{g}$±0.00	1.55^{g}±0.07	6.35^{h}±0.07	74.90^{a}±1.48	8.60^{cd}±1.62
BO.5	9.20^{cd}±0.00	1.30^{de}±0.00	1.90^{de}±0.00	7.45^{c}±0.07	73.82^{abc}±0.06	6.33^{f}±0.13
B0.3	8.75^{d}±0.00	$1.28d^{ef}$±0.04	1.68^{fg}±0.11	7.25^{d}±0.07	74.14^{abc}±0.08	6.92^{ef}±0.00
B0.1	8.25^{e}±0.07	1.23^{efg}±0.04	1.50^{g}±0.00	7.00^{e}±0.00	74.25^{abc}±0.00	7.78^{de}±0.11
BC	7.20^{f}±0.14	1.15^{g}±0.00	1.25^{h}±0.07	6.55^{g}±0.07	74.42^{ab}±0.11	9.43^{c}±0.25

SD = sun dried, OV = oven dried, UB0.5 = unblanched at 0.5 conc., UB0.3 = unblanched at 0.3 conc., UB0.1 = unblanched at 0.1 conc., UBC = unblanched control, B0.5 = blanched at 0.5 conc., B0.3 = blanched at 0.3 conc., B0.1 = blanched at 0.1 conc., BC = blanched control. Values are mean of triplicate observation ±SD, values on the same column with different superscripts are significantly different (P<0.05)

effectiveness of the preservative (citric acid). This may have been caused by the breakdown of protein into different amino acids by the acid (Zulqarnian et al., 2012). The fat and ash content were significantly different at various levels of preservation. This ranged from (1.15, 1.25) in BC to (7.15) in OV, and (11.25) in SD, respectively. The higher values recorded for the dried samples can be attributed to loss of moisture which concentrated the nutrient in the samples, while the lower values obtained in the blanched samples could be attributed to the leaching out of nutrient which happened during heating in water. Fana et al. (2015) reported similar result on orange fleshed sweet potato. Citric acid preserved the ash and fat content of the samples which was observed by the linear reduction in values with decrease in the concentration of the preservative solution used. Jebelli-Javan et al. (2015) also reported similar result on sliced button mushroom. The fibre content was also significant ($P<0.05$) for all the treatments. The values ranged from 6.55 in BC to 15.35 in OV. The higher value obtained for blanched treatment samples when compared to the unblanched could be attributed to the nutrient leaching out during heating in water which gave room for concentration of fibre in the samples. Similar observations was reported by Zhang et al. (2006) on fruits and vegetables, however, Agiriga et al. (2015) and Fana et al. (2015) had a contrary view. Moisture content was significantly different ($P<0.05$) for all treatment samples. It ranged from 8.45% in OV to 74.90% in BC. The low moisture value obtained for the dried samples could be due to loss of moisture during drying. The samples preserved in citric acid and blanched had higher moisture content compared to unblanched samples. This could be as a result of the fact that *Pleurotus pulmonarius* absorbed some of the water that was used in blanching before they were transferred into the preservation solution for storage. Fana et al. (2015), Zhang et al. (2006) and Agiriga et al. (2015) reported similar findings. The lower values obtained in samples stored in higher concentration of citric acid suggest that citric acid treatment prevented the absorption of more water by the sample but rather caused linear loss of water through osmosis. Mujanja et al. (2012) reported similar observation on oyster mushroom. Carbohydrate content ranged from 6.32% in UB0.5 to 30.25% in OV. The higher value of carbohydrate for the dried samples could also be as a result of low moisture content which concentrated the nutrient in the samples. Similar observation was reported by Mujanja et al. (2012).

The result (Table 5) obtained for the sensory evaluation one week after storage showed that colour scores obtained were significant ($P<0.05$). This ranged from 5.40 in OV to 7.40 in B0.5. The higher colour score of the blanched samples suggests that blanching treatment enhanced the colour of the samples during storage. Similar observation has been reported by Zhang et al. (2006) on orange fleshed sweet potato. The low score of OV suggests that the panellists had low preference for it. This could be as a result of the brown appearance which was as a result of milliard reaction caused by heating temperature (Surkiewicz et al., 1975). The texture score ranged from 5.60 in SD to 7.20 in UB0.5. Scores obtained for the other samples were significantly different ($P<0.05$) except for UB0.3 and B0.5 that had similar score (7.00). The texture score suggested that the panellist had higher preference with increase in the concentration of the preserving solution (citric acid). This supports an idea that citric acid can be used to preserve and enhance the texture quality of a food source. Similar result was recorded by Fana et al. (2015) on sweet potato. Values obtained for odour were significantly different which ranged from 7.20 in B0.5 to 5.20 in OV. Blanched samples had higher preference when compared to the unblanched samples. This could be as a result of low microbial load of the blanched samples. Microbial activities cause deterioration of food sources leading to release of foul odour as reported by Fana et al. (2015).

Table 5. Sensory evaluation of *Pleurotus pulmonarius* after one week storage

Treatment	Colour	Texture	Flavour
SD	$6.80^{abc}\pm0.79$	$5.60^{d}\pm1.07$	$5.40^{d}\pm0.97$
OV	$5.40^{d}\pm0.70$	$6.80^{abc}\pm1.23$	$5.20^{d}\pm1.14$
UB0.5	$7.00^{abc}\pm0.94$	$7.20^{a}\pm0.92$	$6.80^{ab}\pm0.92$
UB0.3	$6.60^{abc}\pm0.84$	$7.00^{bc}\pm0.94$	$6.40^{abc}\pm0.84$
UB0.1	$6.40^{bc}\pm0.97$	$6.60^{abc}\pm1.07$	$6.00^{bcd}\pm0.94$
UBC	$6.20^{c}\pm0.79$	$6.40^{abcd}\pm1.07$	$5.60^{cd}\pm0.97$
B0.5	$7.40^{a}\pm0.70$	$7.00^{ab}\pm0.82$	$7.20^{a}\pm0.79$
B0.3	$7.20^{ab}\pm0.79$	$6.60^{abc}\pm1.26$	$6.80^{ab}\pm0.92$
B0.1	$6.80^{abc}\pm0.79$	$6.20^{bcd}\pm0.42$	$6.40^{abc}\pm0.52$
BC	$6.40^{bc}\pm0.84$	$6.00^{cd}\pm0.47$	$6.00^{bcd}\pm0.47$

SD = sun dried, OV = oven dried, UB0.5 = unblanched at 0.5 conc., UB0.3 = unblanched at 0.3 conc., UB0.1 = unblanched at 0.1 conc., UBC = unblanched control, B0.5 = blanched at 0.5 conc., B0.3 = blanched at 0.3 conc., B0.1 = blanched at 0.1 conc., BC = blanched control. 9 = Like extremely, 8 = Like very much, 7 = Like moderately, 6 = Like slightly, 5 = Neither like or dislike, 4 = Dislike slightly, 3 = Dislike moderately, 2 = Dislike very much, 1 = Dislike extremely. Values are mean± SD, values on the same column with different superscripts are significantly different ($P<0.05$)

Two weeks after storage, results (Table 6) showed that the colour score ranged from 3.60 in BC to 6.40 in OV. The reduction in values when compared to week one may be as a result of higher microbial activity which deteriorated the samples. Similar trends was observed in the texture and odour/flavour values which ranged from 3.20 in UBC to 6.60 in B0.5 for flavour and 3.60 in BC to 6.40 in OV for texture. Similar reduction in preference was reported by Ifeoluwa et al. (2015).

Conclusions

Mushroom a rich source of protein, carbohydrate, fats and dietary fibre is very essential to health. Inference could be drawn from the present study that drying (oven drying and sun drying) of oyster mushrooms (*Pleurotus pulmonarius*) can lengthen their shelf life and retain their essential properties, control microbial populations during storage as shown by the low population of bacteria and fungi, and It could also be concluded that citric acid could be classified a good preservative as witnessed in the reduction of the microbial loads when its concentration increased.

The results from the research experience showed that mushrooms with longer shelf-life might be obtained if the concentration of citric acid is increased further than the 0.5% used in this study. This present research also showed that these preservation methods did not prolong the shelf life of *Pleurotus pulmonarius* beyond 7-14 days which demonstrates the need to combine preservation methods as a form of hurdle technology in order to extend the shelf life of mushrooms.

Table 6. Sensory evaluation of *Pleurotus pulmonarius* after two weeks of storage

Treatment	Colour	Texture	Flavour
SD	$6.20^{ab}\pm0.63$	$5.20^{bcd}\pm0.79$	$5.20^{bc}\pm0.79$
OV	$5.00^{cd}\pm0.94$	$6.40^{a}\pm0.52$	$4.80^{bc}\pm0.79$
UB0.5	$6.40^{ab}\pm0.97$	$6.00^{ab}\pm1.15$	$6.40^{ab}\pm0.84$
UB0.3	$5.80^{bc}\pm1.14$	$5.20^{bcd}\pm0.79$	$5.20^{bc}\pm0.79$
UB0.1	$5.20^{cd}\pm0.79$	$4.60^{de}\pm1.07$	$4.40^{cd}\pm0.70$
UBC	$4.60^{d}\pm0.70$	$4.20^{ef}\pm0.63$	$3.20^{e}\pm0.42$
B0.5	$6.80^{a}\pm0.79$	$5.60^{bc}\pm1.35$	$6.60^{a}\pm1.26$
B0.3	$6.20^{ab}\pm1.23$	$5.00^{cde}\pm0.82$	$5.60^{b}\pm0.97$
B0.1	$5.60^{bc}\pm1.07$	$4.20^{ef}\pm0.63$	$4.60^{d}\pm0.97$
BC	$5.00^{cd}\pm0.94$	$3.60^{f}\pm0.52$	$3.80^{de}\pm0.63$

SD = sun dried, OV = oven dried, UB0.5 = unblanched at 0.5 conc., UB0.3 = unblanched at 0.3 conc., UB0.1 = unblanched at 0.1 conc., UBC = unblanched control, B0.5 = blanched at 0.5 conc., B0.3 = blanched at 0.3 conc., B0.1 = blanched at 0.1 conc., BC = blanched control. 9 = Like extremely, 8 = Like very much, 7 = Like moderately, 6 = Like slightly, 5 = Neither like or dislike, 4 = Dislike slightly, 3 = Dislike moderately, 2 = Dislike very much, 1 = Dislike extremely. Values are mean± SD, values on the same column with different superscripts are significantly different (P<0.05)

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