Effect of Different Pretreatments and Drying Methods on The Compositional Quality of Oyster Mushroom

Abdel Monem I. Elbah[1], Ayman Abo El-Yazid[2] and Ahmed E. Abdalla[2]
[2]Food Science Depart.,Fac.Agric.Saba Basha, Alex. Univ.[1]Omar El-Moktar University

ABSTRACT: This study was carried out to evaluate the effect of pretreatments prior different drying methods and temperatures on compositional quality of the dried mushroom. Oyster mushroom (*Pleurotus ostreatus*) was cultivated on rice substrate and collected samples were pretreated (steeped or blanched) by different solutions (0.1% sodium metabisulfite and 0.1 and 0.5% citric acid) and dried using oven at 50°C and 60°C, sun-drying at 30-35°C and microwave drying at 2.45 GHz until reached to constant weight. Rehydration ratio and browning index (color) of the dried oyster mushroom samples were the most effective parameter for judging and selecting the pretreatment and the drying process.Blanching pretreatment seems to elongate drying time compared to control or steeped samples. Control and steeped samples recorded the highest rehydration ratio and lowest browning index compared with blanched samples dried at the same drying temperature. Samples steeped in 0.1% sodium metabisulfite or 0.5% citric acid prior drying had the lowest browning index, while those blanched in the same solutions had the highest browning index values. In general, drying processes has affected on the chemical composition of different samples, especially protein. Moreover, reduction in total microbial counts of dried mushroom samples was recorded. The total amino acid contents of fresh mushroom was in the highest levels followed by steeped pretreatment with 0.5% citric acid prior sun-dried mushroom and oven dried mushroom, while was lowest in microwave dried mushroom. Essential amino acids of fresh mushroom were higher than published by FAO/WHO.In this study, minerals of microwave dried mushroom were in lowest levels. Sun-drying and oven-drying after pretreatments with 0.5% citric acid has no effect on mineral contents in dried mushroom.Total phenol and flavonoids were not affected by oven or sun-drying while there was little effect by microwave drying. On the other hand ascorbic acid was greatly affected by microwave drying. Sensory evaluation revealed that control and samples steeped in 0.5% citric acid prior sun-drying and microwave got higher scores in colour, texture and taste than other oven drying mushroom.

Keywords: *Pleurotus ostreatus*, drying, pretreatment, rehydration ratio, browning index, chemical composition, sensory evaluation.

INTRODUCTION

Mushrooms of *Pleurotus* sp. are commonly called 'Oyster mushrooms'. They are the second most popular mushrooms after button mushroom throughout the world (Adejoye *et al*., 2006, Amin *et al*., 2007 and Stojanova *et al*., 2016) and the most popular mushroom in Egypt. Oyster mushrooms grow over a range of temperature of 15-30^{o}C and thus are suitable for cultivation under both temperate and tropical climatic conditions. Mushrooms are not only found to be medicinally effective as antitumor, antibacterial, antiviral and hematological agents and in immune modulating treatments (Weisburger, 1999 and Patel *et al.*, 2012) but also found to possess significant antioxidant capacity (Prabu and Valli, 2016).

Edible mushrooms have the potential to contribute enormously to food value of our habitual diet as they may contribute largely to the supply of both macro and micro nutrients in our diet. Nutritive value of mushrooms is due to their high content of fibers, essential amino acids, vitamins, minerals and low lipid content (Stamets, 2000, Manjunathan and Kaviyarasan, 2011 and Rashidi and Yang, 2016). Mushroom eaters are generally found to have greater intake

levels of most vitamins and minerals and in some cases to consume less fat and sodium. A greater percentage of mushroom eaters meet the recommended daily allowance (RDA) and daily recommended intake (DRI) for calcium, copper, iron, magnesium, phosphorus, zinc, folate, niacin, riboflavin, thiamin, vitamin A, B6, B12, C, E, energy, carbohydrate, fiber and protein than non mushroom eaters (WHO/FAO, 2004 and Zahid *et al.*, 2010).

Fresh mushrooms tend to lose quality after harvest, mainly because of their high respiration rate and the fact that they have no epidermis to protect them from water loss. Mushrooms are extremely perishable in nature and may not be kept for more than one day after harvesting at ambient conditions. Various physiological and morphological changes occur after harvest, which make these mushrooms unpalatable for consumption (Giri and Prasad, 2013 and Akbarirad, *et al,* 2013).

Drying is one of the important preservation techniques performed for storage of mushrooms and dehydrated mushrooms are valuable ingredients in a variety of food formulations such as instant soups, sauces, snacks, pizzas, and meat and rice dishes. Conventional air drying is one of the most frequently used techniques for mushroom dehydration, which involves thermal and /or chemical pretreatment and drying at temperature maintained between 50 and 70 ^{o}C. Due to long drying time and overheating of surface during hot air drying, the problems of darkening in colour, loss in flavour and decrease in rehydration ability occur. Drying of oyster mushrooms can lengthen their shelf life and retain their properties plus quality as close to the original sample as possible. Low heat air methods are recommended in reducing water activity and keeping proximate contents and quality (Aishah and Rosli, 2013 and Muyanja, *et. al.,* 2014).

Polyphenols and related antioxidants are one of the most important bioactive components in mushrooms. They play an important role in prevention against food oxidation. Unfortunately, conventionally dried mushrooms exhibit low antioxidant retention due to loss of phenolic compounds (Bandoniene *et al*., 2002; Shan *et al*., 2009).
Use of Microwave is considered as the fourth generation drying technology. Hence better rehydration characteristics may be expected in microwave dried products (Korley *et al*., 2014 and Kantrong *et al*., 2014). Microwave processes offer a lot of advantages such as less start up time, faster heating, energy efficiency (most of the electromagnetic energy is converted to heat), space savings, precise process control and food product with better nutritional quality. Microwave drying has been shown to reduce loss of active compounds, e.g. in mint (Arslan *et al*., 2010) and oregano (Jałoszyński *et al*., 2008).

The dehydrated mushrooms can be rehydrated by water immersion before the consumption. The rehydration characteristics of dried products are used as a quality parameter and are taken as indication for physical and chemical changes occurred during the drying process (Hassan and Medny, 2014).

As mushrooms are very sensitive to temperature, choosing the right drying method can be the key for producing high quality dehydrated mushrooms. Therefore, the present study aimed to evaluate the effect of pretreatments prior different drying methods and temperatures on compositional quality of the dried mushroom, which will define the optimum drying conditions for *Pleurotus* mushroom.

MATERIALS AND METHODS

Standards and Reagents

All chemicals, solvents and standards were of analytical grade and purchased from Sigma (St. Louis, MO, USA).

Methods

1. Growing of oyster mushroom

Fresh oyster mushroom fruit bodies of *Pleurotus ostreatus* were cultivated in Faculty of Agriculture, Saba Basha, Alexandria University, Egypt in March-May, 2016.

Rice substrate was mixed with 1% w/w of Calcium carbonate ($CaCO_3$) and soaked in tap water and autoclaved at 120 - 125°C for an hour and allowed to cool overnight. After cooling, one kg autoclaved substrate mixed with about 2.5% grain spawn (obtained from Botany Department, Faculty of Agriculture, Alexandria University) was filled in the polypropylene bag of 25cm × 15cm in size. The plastic bags were placed in the growing room of temperature between 22 ± 2°C, relative humidity 75 ± 5 % and light intensity of 250 ± 100 lux.

Fruiting bodies from the first and second flushes were used. Freshly harvested fruit bodies, free from visual blotches, were placed in cold storage at 4°C before drying.

2. Samples pretreatment

Harvested fresh oyster mushrooms were washed with potable tape water and then with distilled water in order to remove bedding material and contaminants. Fresh mushrooms were dried off from excess water, cut into slices (about 10 mm thickness). Three kilograms of fresh oyster mushroom were divided into 6 equal parts, each of them was subjected to one of the following treatments:

1- Control (untreated).
2- Stepping for 10 min in 0.1% sodium metabisulphite (SMS) at room temperature (20 ± 2 °C).
3- Stepping for 10 min in 0.1% citric acid (0.1%) at room temperature (20 ± 2 °C).
4- Stepping for 10 min in 0.5% citric acid (0.5%) at room temperature (20 ± 2 °C).
5- Blanching for 2.0 min at 90 ± 2 ^{O}C in 0.1% sodium metabisulphite (SMS).
6- Blanching for 2.0 min at 90 ± 2 ^{O}C in 0.5% citric acid (0.5%).

3. Drying methods

The mushroom slices were drained and spread in a single layer in stainless steel trays and dried by different methods:

1- Air ventilation oven at 50 ± 5 ^{O}C until reaching to constant weight. Air was heated electrically before entering the dryer.
2- Air ventilation oven at 60 ± 5 ^{O}C until reaching to constant weight.
3- Sun drying at about 32.5±2.5°C at about 81 ± 1 % relative humidity for three continuous days (Suguna *et al*., 1995) until reaching to constant weight.
4- Microwave energy at 2.45 GHz.

Drying time (hrs) for each treatment was recorded. Browning index values and rehydration ratio of the dried mushroom were used as the basis to select the optimum drying treatment.

4. Analysis methods

1. Rehydration ratio

The rehydration ratio of dried mushroom samples was determined by soaking samples with a defined weight of water (approximately 5 g of mushroom in hot water of 300 mL at 85 ± 5°C). Rehydration was carried out till maximum weight of sample was obtained. The samples were then removed, dried off with tissue paper and weighed again. Rehydration ratio was defined as the ratio of weight of rehydrated samples to the dry weight of the sample (Arora *et. al*., 2003).

2. Browning index

The degree of non–enzymatic browning of the dried mushrooms was determined following the method of Mudahar and Bains (1982). The color was extracted from dried mushroom using 60% ethanol, and the absorbance of the filtrate was measured using a spectrophotometer at 440 nm.

3. Proximate analysis

Moisture, crude protein, lipid, ash and fiber contents were determined according to the AOAC (2005). Carbohydrate was calculated by difference. All determinations were performed in triplicates and the means ± standard error was reported.

4. Energy values

Energy values (Kcal/100g) were calculated as reported by Greenfield and Southgate (1992), multiplying the factors, 4, 9 and 4 for each gram of protein, lipids and carbohydrate, respectively. The calorific (energy) value was obtained according to the methods of Akinyeye *et al*. (2010) and Akinyeye *et al* (2011).

5. Microbiological test

Total microbial count was estimated on both fresh and dried mushrooms immediately after drying. Total microbial count was enumerated on plate count agar medium.

6. Extraction

Ten gram of dried and pulverised mushroom was soaked in 200 ml of distilled water for 24 h and the resulting extract was filtered and kept in the refrigerator until when required for analysis.

7. Amino acids composition

Amino acids was determined using a Beckman amino acid analyzer model 119 CL (USA) according to Spackman *et al*. (1958) after hydrolysis with 6N HCl at 110°C for 24 hours and tryptophan was determined colorimetrically after alkaline hydrolysis with 4.2 N NaOH at 110°C for 24 hours according to the method described by Blauth *et al*. (1963).

8. Elements content

Elements content (phosphorus, magnesium, iron, zinc, potassium, calcium and sodium) of dried mushroom powders were determined according to the methods described in AOAC (2005). Calcium and magnesium contents were determined using Double Beam Atomic Absorption, potassium and sodium contents by flame photometer, Corning 410 (Corning Limited Halestead Essex England UK), iron and zinc by Spectrophotmeter 902 GBC and phosphorus by using visible spectrophotometer PU 8650 (Pye Unicam, England).

9. Total phenolic compounds

The amount of total phenolics was determined by using Folin–Ciocalteu method (Amin *et al*., 2006). A 0.5 ml of the methanolic extract was transferred into a test tube and 125 µl of Folin-Ciocalteu reagent (Sigma) was added and mixed. The mixture was allowed to stand at room temperature for 10 min. 125 µl of 20% (w/v) sodium carbonate was added to the mixture and mixed gently and this was left at room temperature for another 60 min. The absorbance of the mixture was recorded at 760 nm using a spectrophotometer (Hitachi, U-1800). Total phenolic compounds were calculated from a standard calibration curve of tannic acid (Fluka).

10. Total flavonoids

Total flavonoids content was determined by the method suggested by Meda *et al*. (2005). In this method, 0.5 ml of 2% aluminium trichloride ($AlCl_3$) in methanol was mixed with same volume of the methanolic extracts (0.1 mg/ml) of mushroom. Absorbance was noted after 10 min of reaction at 415 nm. The concentration of total flavonoids was calculated from the standard quercetin graph.

11. Ascorbic acid

Ascorbic acid was determined according to the method of Klein and Perry (1982). Each dried methanolic extract (100 mg) was re-extracted in 10 ml of metaphosphoric acid (10 mg/ml) for 45 min at room temperature and filtered through a disposable membrane filter (Pore size-0.45 µm) (Millipore, Inc. USA). The filtrate (1 ml) was mixed with 9 ml of 2, 6- dichlorophenol indophenol and the absorbance was measured at 515 nm. Content of ascorbic acid was calculated on the basis of the calibration curve of standard L-ascorbic acid.

5. Sensory evaluation

The quality attributes (color, texture and taste) of fresh and dried (after being rehydrated) mushroom samples were organoleptically judged by a group of ten panelists. One hundred gram of each sample were sauteed in butter (10g), salted then served as reported by Komanowsky *et al*. (1970). These qualities were scored on a scale of one to ten.

RESULTS AND DISCUSSION

1. Effect of pretreatments and drying methods on drying time, rehydration ratio and browning index of oyster mushroom.

Four different drying methods included oven drying at 50°C and 60°C, sun drying at 32.5±2.5°C as well as microwave drying at 2.45 GHz were carried out on oyster mushroom. Moreover mushroom samples were **steeped** in 0.1% sodium metabiosulphite (SMS) or 0.1 and 0.5 citric acid for 10 min or blanched in sodium metabiosulphite (SMS) or citric acid for 2 min prior drying.

The results of effect of pretreatments and drying methods on drying time, rehydration ratio and browning index of oyster mushroom are shown in Table (1).Drying time was distinctly affected by drying temperature and pretreatments. Drying time ranged between 25 min up to 18 hr for all drying temperature and pretreatments. It could be observed that, control (untreated) showed the shortest drying time at any drying temperature, while blanching pretreatment seems to elongate drying time compared to control or steeped ones. These results are confirmed by the findings of many authors (Arora *et. al.,* 2003, Tulek, 2011 and Kumar *et. al.,* 2013).

These results indicated that drying times of steeped mushroom in 0.1% SMS similar to the level of steeped mushroom in 0.5% citric acids in all drying temperatures.

Higher rehydration ratio indicates better dried product. Rehydration ratio was affected by pretreatment with drying methods and temperatures. Generally, high drying temperature (60^{o}C) exhibited low rehydration values (2.68 – 5.88), while low drying temperature (50^{o}C), sun drying at 30-35 ^{o}C and microwave drying showed higher rehydration values (3.77- 7.05, 4.04- 7.46 and 4.66-7.88, respectively). Blanching mushroom samples in different tested solution prior drying resulted in the lowest rehydration values which highly differed compared to the control or those steeped in the same solution at room temperature.

The poor rehydration ratio of blanched samples could be due to the effect of heat treatment on the protein structure and the permeability of the cell walls of the mushrooms. In this respect, Konanayakam and Sastry (1988) stated that, blanching with hot water or steam at high temperature causes undesirable changes in product texture and also inherently linked to weight and nutritional quality losses in the product**.** Riaz *et. al.* (1991) concluded that untreated (control) dried mushroom samples, were higher in rehydration ratio compared to blanched ones. They also stated that blanching as pre-treatment yielded structurally more compact product after drying and this factor adversely

influenced the rehydration of blanched mushrooms. Jayathunge and Illeperuma (2001) declared that, the higher rehydration ratio observed in their study may probably be due to minimum changes in the structure of proteins and consequently minimum changes in protein functionality at the low drying temperature of 45°C. Kumar *et. al*., (2013) recorded that, the mushrooms dried in medium size dryer using pretreatment of 1.0% potassium metabisulphite gave the maximum rehydration ratio and coefficient of rehydration.

Increasing drying temperature increased firmness of the product probably because the mushrooms dried faster thus the time for the breakdown of the cell structural components like pectin or cellulose were reduced (Mohamed and Hoo (1994). Kulshreshtha *et. al* .(2009) mentioned that, the rehydration ratio of dried samples was higher at the lower drying temperatures and was the highest at 60^{o}C. Rehydration ratio ranged from 2.563 to 4.015 for different operating conditions. Nour *et. al.* (2011) found that, the sliced button mushrooms dried at lower temperature had greater rehydration ratio as compared with the sample dried at higher temperature. They stated that, at lower temperatures, less cellular destruction and dislocation occur thus, the material is capable of absorbing more water. Apati *et. al.* (2010) stated that**,** the rehydration capacity decreased with increasing drying temperature, which could be associated to the stronger mushroom structure deformation at higher temperatures. The minimum rehydration ratio of 2.18 was obtained for blanched slices treated.

The results in this study indicated that rehydration ratio of steeped mushroom in 0.1% SMS at the same level of steeped mushroom in 0.5% citric acids in all drying temperatures.

Browning index values were represented as absorbance at 440nm. The absorbance value for fresh oyster mushroom was 0.018 and which increased by different manners according to pretreatment and drying methods and temperatures. Generally, pretreated mushroom samples with 0.1% sodium metabisulphite (SMS) or 0.5% citric acid either by steeping or blanching retarding browning. The lowest browning index values were recorded to steeped 0.1% SMS and 0.5% citric acid, 0.162 and 0.169 prior sun-drying followed by 0.180 and 0.166 for steeped mushroom samples prior microwave drying followed by 0.181 and 0.179 for steeped mushroom samples prior oven drying at 50°C. Browning index values were high in mushroom samples pretreated with blanching in 0.1% SMS or 0.5% citric acid.

Darkening or browning of dried mushrooms could be attributed mainly to enzymatic browning, Millard reactions, oxidation of phenolic compounds or microbial activities. In this respect, Komanowsky *et. al.,* (1970) revealed that, mushroom varieties discoloration was proportional to the amount of heat treatment and lower drying temperatures yielded lighter product. Blanching for 2.0-10 min. caused excessive darkening during drying. Visual inspection revealed that pretreatment of mushroom pieces with citric acid, table salt, ascorbic acid, EDTA or sodium acid pyrophosphate had little effect on color of dried mushroom. Among the chemical tested for pretreatment, only sodium bisulfite was found to decease mushroom discoloration during drying. They also concluded that, blanched mushrooms darken when they are exposed to hot air

during drying. Products with good flavor, storage stability and a better color and shape were obtained by dehydrated non-blanched mushrooms**.**

Generally the browning of the dried mushroom product is more pronounced at higher temperatures (Kulshreshtha *et. al.,* 2009). The total colour change was greater in the samples dried at higher temperature. This implies that with increase in air temperature, the degradation rate of colour becomes faster as a result of high energy transferred to the inside of food material. The main factor causing colour changes during hot-air drying is enzymatic and non-enzymatic browning reactions. Lowering the drying air temperature resulted in lower thermal stress on the surface and a higher whiteness index was obtained (Nour *et al.,* 2011). The mushrooms dried in medium size dryer using pretreatment of 1.0% potassium metabisulphite gave the maximum values of whiteness (Kumar *et al.,* 2013).

According to the results of rehydration ratio and browning index obtained from Table (1) it could be clearly recommended that, control (untreated) and steeped in 0.1% SMS or 0.5% citric acid prior sun drying or at 50 ^{o}C and microwave drying are the optimum drying conditions for oyster mushroom from quality point of view. So, only the aforementioned samples were selected to complete the course of this investigation.

2. Influence of pretreatment with 0.5% citric acid and drying methods on the proximate analysis, energy value and total microbial count of the dried mushroom

Samples of oyster mushroom pretreated by steeping in 0.5% citric acid as well as control (untreated) prior drying by hot air at 50 °C , sun-drying and microwave drying were analyzed for moisture , crude protein, ash, crude fat, carbohydrates, energy and total microbial counts immediately after drying (Table 2).

Moisture content of mushroom samples steeping in 0.5% citric acid was from 89.21 % for fresh to be (7.94-8.21%) for dried ones. These results for moisture are lower than those obtained by Kulshreshtha *et. al.* (2009) who recorded that, milky mushroom slices were dried from an initial moisture content of approximately 90% to the final moisture content of about 10% in a fluidized bed dryer. Nour *et al*. (2011) declared that, the moisture content of the fresh button mushrooms (both untreated and treated samples) was found in range of 90-91 % which reduced to 9-12 % after tray drying for various temperatures of air drying. Also, Tulek (2011) found that, the final moisture content of dried *P.ostreatus* was 10%.

Methods of drying caused a sharp decrease in moisture content and consequently led to an increase in protein and ash while there were no effect on fiber and fat contents. A decrease pattern in protein content caused by drying process was detected. Protein contents were more decreased in dried mushroom samples by microwave drying. The lower protein content of dried oyster mushroom may be due to leaching out during dripping and/or loss throughout browning reactions. Many authors confirmed these findings. Blanching mushrooms with hot water or steam at high temperature causes

undesirable changes in product texture and also inherently linked to weight and nutritional quality losses (Konanayakam, and Sastry, 1988 and Martinez-soto *et al*., 2001). The lower protein content of dried oyster mushrooms could be explained by the much greater protein solubilization during brining for a longer time (Muyanja *et. al.,* 2014).

Similarly, the energy values increased due to the drying process as compared to the fresh oyster mushroom as shown in Table 2. The data had the same trend of those obtained by Khaled (1988, 1997), Zaki *et al*. (1993), Baker (2002) and Hassan (2002).

Drying process caused a dramatically decrease in total microbial count. Among dried mushroom samples, 0.5% citric acid steeped samples showed the lowest total microbial count, while control samples were on the contrary (Table, 2). In this respect, Komanowwsky *et. al.* (1970) stated that, fresh mushroom of good quality have over one million bacteria /g. After drying the total bacterial colonies/g were ranged between 5 – 8.60 × 10^3 according to drying conditions and sulfitation (200 ppm SO_2) prior drying recorded the lowest counts . Lakshmipathy *et. al.,* (2013) reported that, open sun dried mushrooms had a significant higher number of microorganisms than all other dehydrated mushrooms. Higher moisture content of the open dried mushroom compared to other dryers could have influenced the microorganism on the dried mushrooms. They referred that the objective of drying is to remove water to a level at which microbial spoilage and deterioration reactions are greatly minimized.

3. Amino acids composition of dried mushroom powders

The amino acids composition of oven-dried at 50°C, sun-dried at 30-35°C and microwave drying mushroom powders pretreated with 0.5% citric acid, expressed as g amino acid /100g protein are shown in Table 3. The data indicated that glutamic acid, aspartic acid, alanine and lysine were the most abundant and dominant amino acids followed by serine, valine, isoleucine leucine and arginine. Cystine, methionine, tryptophan and histidine were found in small amounts in all mushroom samples. The obtained results are in the same trend with those reported by Alofe (1991), Ortega *et al*. (1992), Manzi *et al*. (1999), Abdel-Hakem (2002), Mattila *et al*. (2002), Mendez *et al*. (2005), Chirinang and Intarapichet (2009) and Victor *et al*. (2013).

The total amino acid contents of fresh mushroom was the highest followed by sun-dried mushroom and oven dried mushroom, while was lowest in microwave dried mushroom. Essential amino acids of fresh mushroom were higher than published by FAO/WHO (1991).

The loss of some amino acids during the heat treatment of seeds of bean may be associated with reactions in food as denaturation or interaction with other substances (Slupski, 2010).

The heat treatment did not affect the amino acids content of the milk during pasteurization (g amino acid/100 g sample), and did not influence the amino acids composition of the protein (g amino acid/100 g protein) and the biological value of the protein (Albert, 2009 and Varga-Visi *et al*., 2009).

4. Minerals content of dried mushroom

The contents of Ca, K, P, Na, Mg, Zn and Fe in oven-dried mushroom, sun-dried and microwave dried mushrooms pretreated with 0.5% citric acid are presented in Table 4.

The data indicated that K content (3.1 – 3.8%) was the highest, whereas Zn (35-58 ppm) and Fe (146-214 ppm) contents were the lowest. The rest of mineral were Ca (0.20-0.38%), P (0.28-0.40%), Na (0.42-0.55%) then Mg (0.12-0.16 %) in all dried mushroom powders, respectively. These data are in good agreement with those obtained by Mattila *et al*. (2002); Baker (2002), Hassan (2002) and Zaghloul *et al.* (2007).

In this study, minerals of microwave dried mushroom were in lowest levels. Sun-drying and oven-drying after pretreatments with citric acid has no effect on minerals of dried mushroom.

Manzi *et al*. (1999) who found that, the most abundant mineral element in oyster mushroom was K and they have reported that, the low concentration of Na and the high concentration of K suggest the utilization of mushrooms as an anti-hypertensive diet.

The fructifications of mushroom are characterized by a high level of well assailable mineral constituents (Mattila *et al*., 2002). But the whole mineral level depends, among other things like the species and age of the mushrooms, the diameter of the pilei and on the substratum (Demirbas, 2001).

Mushrooms are reported to contain some important minerals like Ca, Fe, Zn, P, etc. (Mishra, 2016). Results obtained for the zinc concentration are within range of 35-58 ppm as reported earlier.

Microwave interactions with foods depend heavily on salt and moisture content. Water selectively absorbs the energy (Mudgett, 1990). In intermediate and high moisture products, the water, not the solids, absorbs the microwave energy (Mudgett, 1989). However, because of their high heat capacity, they tend to heat unevenly. In drier products, the dissolved salts are concentrated (in the remaining water); if the solids exceed saturation level and precipitate, their ionic conductivities are limited. However, the solids themselves do absorb energy (Mudgett, 1989). Low moisture products generally heat more evenly due to their low heat capacity (Schiffman, 1986).

The major food components included carbohydrates, lipids, proteins and salts (minerals) interact differently with microwave. Because the primary mechanisms of microwave heating are dipole rotation and ion acceleration.

5. Concentration (mg/g) of total phenolic, ascorbic acid and total flavonoids in a methanolic extract of dried oyster mushroom

The amount of total phenolic, ascorbic acid, and flavonoids in the mushroom extracted with methanol was determined (Table 5).

Total phenol was not affected by oven or sun-drying while there was effect by microwave drying. Phenolics are important constituents with scavenging ability due to their hydroxyl groups and hence may contribute directly to the antioxidative action. In the present study, the total phenolic content of fresh oyster mushroom was found to be high i.e., (55.20 mg/g), compared to the reported values in oyster mushroom (15.7 mg/g) (Yanga *et al*., 2002 and Mau *et al*., 2004).

Ascorbic acid is one of the most sensitive vitamins. For this reason, it is often used to evaluate the influences of food processing on vitamin contents (Bognár *et al*.,1989).

Ascorbic acid was reported to interact directly with radicals such as O^{-2} and OH^{-} in plasma, thus preventing damage to red cell membranes. It also assists α-tocopherol in inhibition of lipid peroxidation (LPO) by recycling the tocopherol radical (Beyer, 1994). In the present study, the ascorbic acid contains was in highest level in fresh oyster mushroom (8.8 mg/g), while it was in lowest level in microwave drying oyster mushroom (5.3 mg/g).

Vitamin C can decrease about 20% even at two minutes of microwave treatment. 10 minutes of microwave treatment destroys more than half of vitamin C. (Csapo *et al*., 2009).

The loss of ascorbic acid can probably be ascribed to water leaching and its thermal degradation, as already reported by Lee and Kader (2000). However, steam-blanched, steam-boiled, microwaved, and stir-fried cauliflower had significantly the highest retention of ascorbic acid content. Boiling leads to high losses in ascorbic acid content levels while stewing, steaming, microwave cooking, and even pressure steaming cause only small losses. Stir-frying resulted in a better retention of ascorbic acid content than cooking with a lot of water or using a microwave (Fouad and Ali, 2013)

Flavonoids occur throughout the entire plant kingdom. The most widely distributed flavonoids, flavone and flavonols are mainly hydroxylated in the β-ring at the 3′- and 4′- positions (rutin) followed by the 4′- position (naringenin) (Jayakumar *et al*. 2006, 2009). Many flavonoids and related compounds are reported to possess strong antioxidative characteristics. In this study, flavonoids contents were in high level in fresh mushroom and decreased in microwave drying mushroom.

6. Sensory evaluation of mushroom samples

Data presented in Table (6) declare that, fresh mushroom samples of sun-dried and microwave drying oyster mushroom got the highest scores for all tested sensory attributes and differed than other dried ones. As for color, texture and taste of dried tested mushrooms steeped in 0.5 citric acid prior sun-drying

and microwave drying got the highest score and ranked the second order after fresh followed by control samples. These results were in agreement with the results of Bhattacharya *et al*. (2014).

Kulshreshtha *et. al.* (2009) stated that, drying air temperature of 50 ^{o}C is better as it gives dried product with higher rehydration ratio, lower shrinkage and better color. Drying of oyster mushrooms using Low Heat Air Blow method can lengthen their shelf life and retain their properties plus quality as close to the original sample as possible (Aishah and Rosli, 2013). Arora *et al.* (2003) reported that, sulphitation prior to drying is usually carried out to control non–enzymatic browning in order to improve acceptability of the products.

CONCLUSSION

According to the obtained results throughout this course of study, it could be concluded that, the compositional quality of dried oyster mushrooms depends significantly on the type of pretreatments and drying methods used. Control and steeped dried samples in 0.1% sodium metabisulfite or 0.5% citric acid had higher rehydration ratio and lower browning index than blanched ones. Drying process caused a considerable decrement in protein content and a severe reduction in total microbial counts of mushroom samples. The total amino acids content of fresh mushroom was in the highest levels followed by sun-dried mushroom and oven dried mushroom, while was lowest in microwave dried mushroom. Sun-drying and oven-drying after pretreatments with citric acid has no effect on minerals of dried mushroom while microwave drying was greatly affected on minerals content. Total phenolic and flavonoids were not affected by oven or sun-drying while there was little effect by microwave drying. On the other hand, ascorbic acid was greatly affected by microwave drying. Sensory evaluation revealed that control and samples steeped in 0.5% citric acid prior sun-drying and microwave got higher scores in colour, texture and taste than other oven drying mushroom.

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Table (1). Effect of pretreatments and drying methods on drying time, rehydration ratio and browning index of oyster mushroom.

Prtreatments	Drying time (hrs)	Rehydration ratio	Browning index
Oven Drying at 50 °C			
Control	09.5	7.05 ±0.58	0.228 ±0.05
Steeping in 0.1% SMS	10.0	6.44 ±0.35	0.181 ±0.04
Steeping in 0.1% Citric acid	10.5	6.61 ±0.28	0.175 ±0.02
Steeping in 0.5% Citric acid	10.5	6.55 ±0.38	0.179 ±0.02
Blanching in 0.1% SMS	11.5	4.04 ±0.38	0.210 ±0.02
Blanching in 0.5% Citric acid	11.0	3.77 ±0.36	0.202 ±0.02
Oven Drying at 60 °C			
Control	8.0	5.88 ±0.44	0.346 ±0.03
Steeping in 0.1% SMS	9.0	4.86 ±0.32	0.244 ±0.02
Steeping in 0.1% Citric acid	9.5	4.98 ±0.32	0.254 ±0.02
Steeping in 0.5% Citric acid	9.5	4.88 ±0.34	0.236 ±0.02
Blanching in 0.1% SMS	10.5	2.96 ±0.21	0.238 ±0.03
Blanching in 0.5% Citric acid	10.5	2.68 ±0.24	0.221 ±0.02
Sun- Drying at 30 - 35 °C			
Control	14.0	7.46 ±0.50	0.212 ±0.03
Steeping in 0.1% SMS	16.0	6.66 ±0.22	0.162 ±0.02
Steeping in 0.1% Citric acid	16.5	6.32 ±0.20	0.169 ±0.02
Steeping in 0.5% Citric acid	16.5	6.64 ±0.24	0.160 ±0.03
Blanching in 0.1% SMS	18.5	4.14 ±0.32	0.198 ±0.02
Blanching in 0.5% Citric acid	18.0	4.04 ±0.22	0.188 ±0.02
Microwave Drying			
Control	0.25	7.88 ±0.40	0.214 ±0.01
Steeping in 0.1% SMS	0.30	6.86 ±0.30	0.180 ±0.02
Steeping in 0.1% Citric acid	0.30	6.46 ±0.30	0.188 ±0.02
Steeping in 0.5% Citric acid	0.30	6.82 ±0.30	0.166 ±0.02
Blanching in 0.1% SMS	0.40	5.16 ±0.20	0.178 ±0.02
Blanching in 0.5% Citric acid	0.35	4.66 ±0.20	0.176 ±0.02

Table (2). Influence of some pretreatments and drying methods on the proximate analysis, energy value and total microbial count of the produced dried mushroom powders.

Analysis (%)	Fresh		Oven Drying at 50 °C		Sun- Drying at 30-35 °C		Microwave Drying	
	Wet weight basis	Dry weight basis	Control	Stepped in 0.5% citric acid	Control	Stepped in 0.5% citric acid	Control	Stepped in 0.5% citric acid
Moisture	89.21+0.04	-	8.36+0.02	8.12+0.02	8.04+0.05	7.94+0.05	8.26+0.02	8.16+0.02
Protein	3.16+0.02	24.71+0.15	19.88+0.06	19.38+0.06	19.42+0.09	18.92+0.09	17.08+0.06	17.48+0.06
Ash	0.79+0.01	6.18+0.11	7.19+0.03	7.19+0.03	6.66+0.02	6.66+0.02	7.55+0.03	7.68+0.03
Crude fat	0.22+0.01	1.72+0.07	1.53+0.06	1.50+0.06	1.58+0.07	1.58+0.07	1.43+0.06	1.44+0.06
Fiber	0.96+0.01	7.51+0.02	7.11+0.05	7.11+0.05	7.62+0.02	7.62+0.02	7.41+0.05	7.66+0.05
Carbohydrates (by difference)	5.66+0.18	59.88+0.20	56.63+0.22	56.70+0.22	56.68+0.02	57.28+0.20	58.27+0.20	57.58+0.24
Energy value (kcal/100g)	37.26	353.84	317.01	317.82	318.62	319.02	314.27	313.20
Total count (CFU×10^3/g)	4.9±0.300	-	1.8±0.624	1.3±0.436	4.9±0.300	4.1±0.200	1.3±0.436	1.2±0.226

Table (3). Amino acids composition of dried mushroom powders

Amino acids	g amino acids/100g protein				
	Fresh dried mushroom powder	Oven dried mushroom powder	Sun-dried mushroom powder	Microwave dried mushroom powder	FAO/WHO Pattern(1991)
Glutamic acid	11.88	11.50	11.66	11.44	
Threonine	3.92*	3.86*	3.90*	3.50*	3.50
Serine	5.16	4.64	5.18	4.14	
Aspartic acid	8.66	8.22	8.48	8.10	
Valine	5.88*	5.18*	5.56*	5.12*	5.00
Glycine	3.76	3.60	3.70	3.40	
Alanine	7.24	6.76	6.98	6.44	
Cystine	1.42*	1.16*	1.33*	1.10*	1.88
Proline	4.64	4.16	4.44	4.10	
Methionine	1.38*	1.34*	1.39*	1.12*	2.50
Isoleucine	5.14*	4.76*	4.94*	4.54*	2.80
Leucine	5.92*	5.88*	5.98*	5.46*	6.60
Tyrosine	3.50*	3.36*	3.52*	3.22*	6.30
Phenyl alanine	3.18*	2.94	3.02	2.82	
Histidine	1.94	1.73*	1.82*	1.60*	1.70
Lysine	6.66*	6.35*	6.48*	6.12*	5.80
Arginine	5.68	5.52	5.38	5.30	
Tryptophan	1.16*	1.20*	1.20*	1.12*	1.00
Essential A.A.	38.16	34.82	36.12	33.08	37.08
Non E.A.A.	48.96	47.34	48.84	45.74	
Total A.A.	87.12	82.16	84.96	78.82	

Table (4). Minerals content of dried mushroom

Samples	Minerals content						
	Ca %	K %	P %	Na %	Mg %	Zn mg/kg	Fe mg/kg
Fresh-dried mushroom	0.38	3.8	0.39	0.55	0.16	58	214
Oven – dried mushroom	0.35	3.4	0.40	0.52	0.14	55	188
Sun-dried mushroom	0.36	3.7	0.37	0.51	0.15	54	211
Microwave-dried mushroom	0.20	3.1	0.28	0.42	0.12	35	146

Table (5). Concentration (mg/g) of total phenolics, ascorbic acid and total flavonoids in a methanolic extract of dried oyster mushroom

Compound	Concentration (mg/g)			
	Fresh	Oven-drying	Sun-drying	Microwave
Total phenol (expressed as tannic acid equivalent)	55.2±1.24	53.4±1.14	54.2±1.44	50.1±1.06
Ascorbic acid	8.8±0.43	8.0±0.22	8.4±0.43	7.3±0.88
Flavonoids (expressed as quercetin equivalent)	4.9±0.05	4.2±0.06	4.7±0.05	4.0±0.06

Table (6). Sensory evaluation of fresh and dried mushrooms

Samples	Color	Texture	Taste	Overall acceptability
Fresh-dried mushroom	7.8 ±0.32	7.4 ±0.33	7.2 ±0.48	7.5 ±0.40
Oven –dried mushroom	6.7 ±0.28	6.4 ±0.26	7.0 ±0.34	6.7 ±0.41
Sun-dried mushroom	8.3 ±0.44	6.9 ±0.44	6.8 ±0.42	7.3 ±0.33
Microwave-dried mushroom	8.1 ±0.50	7.2 ±0.28	6.8 ±0.21	7.4 ±0.28

الملخص العربى

تأثير المعاملات الأولية المختلفة وطرق التجفيف على الجودة التركيبية لعيش الغراب المحارى

عبد المنعم إبراهيم الباح[1] – أيمن أبواليزيد – أحمد السيد عبدالله

قسم علوم الأغذية – كلية الزراعة سابا باشا – جامعة الإسكندرية – مصر

جامعة عمر المختار – ليبيا[1]

أجريت هذه الدراسة لتقدير تأثير المعاملات الأولية قبل طرق التجفيف المختلفة (على درجات حرارة مختلفة) على الجودة التركيبية لعيش الغراب المحارى. حيث تم معاملة عيش الغراب المحارى المنزرع على قش الأرز سواء بالغمر على درجة حرارة الغرفة لمدة 10 دقائق أو بالسلق على درجة حرارة 90°م لمدة دقيقتين بإستخدام محاليل 0,1 صوديوم ميتاباى سلفيت أو 0,1 وكذا 0,5 حمض الستريك ثم تم التجفيف بإستخدام الفرن على درجة حرارة 50 °م , 60 °م والتجفيف الشمسى على درجة حرارة من 30– 35 °م وكذا التجفيف بإستخدام الميكروويف على 2.45 GHz حتى الوصول إلى وزن ثابت. وتم إجراء التحاليل المختلفة على العينات التي تم تجفيفها بالطرق المختلفة وتم تقييم الجودة التركيبية للمنتج. وكانت نسبة التشرب (الإسترجاع) ومعامل التلون البنى (اللون) للعينات هي أهم العوامل للحكم على جودة المنتج وإختيار أهم المعاملات الأولية وطرق التجفيف.

أوضحت النتائج أن سلق العينات قبل التجفيف يؤدى إلى زيادة فترة التجفيف وإغمقاق لون العينات مقارنة بالعينات غير المعاملة أو التي تم غمرها لمدة 10 دقائق والتي كانت مدة تجفيفها أقل ولونها أفضل. وقد أثرت طرق التجفيف على التركيب الكيماوى والميكروبيولجى لعينات عيش الغراب المحارى المجففة حيث إنخفضت نسبة البروتين كما إنخفض المحتوى الميكروبى. وقد أثر التجفيف بالميكروويف على كل من محتوى الأحماض الأمينية ونسبة المعادن وحمض الأسكوربيك أكثر من التجفيف الشمسى والتجفيف في الفرن على درجة 50 °م.

وأوضحت الإختبارات الحسية أن العينات غير المعاملة والعينات التي تم غمرها في 0,5 حمض الستريك قبل التجفيف الشمسى والتجفيف بالميكروويف كان لها أعلى معدلات في اللون والقوام والطعم.