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Effect of processing and storage on physical and texture qualities of oyster mushrooms canned in different media

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ABSTRACT

This study evaluated the influence of packing medium on some physicochemical, textural, and microbial properties of canned oyster mushrooms during storage. Mushrooms canned in brine or oil was stored at room temperature for six months. During this period pH, leached solids, drained weight, instrumental color, and texture were evaluated by standard methods. The results showed a 21% and 64% reduction in mushroom hardness after blanching and canning respectively. The pH of canning media ranged from 6.4 to 6.5 for brine and 5.6 to 5.8 for oil, during storage. Drained weight was higher in oil (124 – 127 g) compared to brine (104 – 120 g) whereas the extent of leaching was higher for mushrooms canned in brine. Mushrooms in brine were firmer (8.8 N) and chewier (3.6 N), compared to those canned in oil (7.6 N and 4.1 N). A significant reduction in firmness was recorded after the sixth month in both media. Color, chewiness, and springiness of the canned mushrooms were stable during the six-month storage period. The study showed that whereas brine provided good stability in pH and color, oil was a better medium for reducing leaching and maintaining the drained weight of canned mushrooms during storage.

Introduction

Mushrooms are fast growing fungi that produce fleshy fruit bodies with valuable nutritional components. They are popular and accepted worldwide as a delicacy and component of many diets. Production and consumption of mushrooms in many countries have seen a steady rise because of both their nutritional and medicinal or nutraceutical properties [6]. In many developing countries, production is mainly undertaken by small and medium scale enterprises. Among the over 20 species of mushrooms grown globally, button/white, shiitake, and oyster mushrooms are the most dominant. Mushrooms are low in calories and rich in minerals, vitamins and dietary fiber. They contain up to 95% moisture, less than 10% fat (db) and more than 16% protein (db), and good levels of amino acids such as glutamic acid, aspartic acid, alanine and arginine [26]. Apart from these nutritional components, mushrooms also have medicinal properties such as anti-inflammatory and immunostimulatory activities [13].

Mushroom is an important food and a good alternative to meat. It is used in the preparation of many soup and stew based cuisines globally [3,16]. Fresh mushrooms generally have a short shelf life of nearly up to three days at ambient tem-

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perature [18]. This is because of their high moisture content, extremely high respiration rate, enzyme activity and bacteria attack. In addition, they lack an epidermal structure and therefore lose water rapidly through transpiration [11]. As a result, they wilt, lose their appealing properties, and become unacceptable to consumers. Additionally, postharvest practices such as handling, transportation, and storage may also contribute to early spoilage. Many of these methods have been useful in preserving mushrooms for extended periods. Technologies available for processing mushrooms including cooking, pickling, frying, drying and gamma irradiation have been widely studied [12,15,17,24]

Canning presents a unique approach to oyster mushroom preservation because it keeps the mushrooms in a moist state. This method of preservation gives food a longer shelf life. In canning, food is sealed airtight in a container to prevent contamination by microorganisms, and sterilized with heat to prolong shelf life. Commonly, the food is packed in liquid medium such as brine or oil, and transfer heat from the retort to the food [19,20]. This is an important component in canning and influences the quality of the canned product. For instance, Medina et al., [19] explain that brine establishes an aqueous environment, which predisposes canned tuna lipids to oxidation. Also, the results of a study by Naseri et al., [20], indicated that the fat composition of silver carp was similar to the of the fat used as packing medium since canning led to the exchange of fatty acids between the product and packing media.

Previous mushroom canning studies either focused on the effect of processing on chemical constituents, texture and other quality features, without elucidating the effect of packing medium and storage on product quality indices. Arumuganathan et al., [4] reported an improvement in the quality of button mushrooms canned in brine after optimizing the pretreatment operations such as blanching time, soaking and concentration of EDTA. Czapski [9] also evaluated the effect of pretreatment on the yield and quality of blanched mushrooms canned in brine. Additionally, textural changes that occur during canning and storage of two species of mushrooms were studied by Jaworska et al. [30]. Since the packing medium is influential in canning, some differences may be expected in some quality indices of canned mushrooms (such as pH, drained weight, color, etc), when different packing medium is used.

This study aimed to evaluate the effect of packing medium on some quality indices of canned oyster mushrooms during storage. Brine and refined vegetable oil were used in the canning operation and their effect on the physicochemical, textural, and microbial properties of canned mushrooms compared during storage.

Materials and methods

Oyster mushrooms (*Pleurotus ostreatus*) harvested from a cropping facility in CSIR-Food Research Institute, Ghana were used for the study. The mushrooms were cleaned with a moist cloth to remove any foreign materials. Mushrooms were trimmed of all unwanted parts and washed in potable water before processing. The washed whole fruiting bodies were blanched in steam (at atmospheric pressure) for 3 min before immediately filling manually into previously steam-sterilized 2-piece cans. Oyster mushrooms were either canned in brine (2% salt solution), or refined vegetable oil. Hot canning medium (80 °C) was filled into the loaded cans (leaving a ½ inch headspace) before applying the can lids and sealing with a semi-automated seamer. The total weight of each can was approximately 190 g. Cans were sterilized in an autoclave at 121 °C for 30 min. Analysis was carried out after canning (Month 0), 1, 3, and 6 months in storage at room temperature.

Analyses

Drained weight

Drain weight was determined following Codex STAN 94-1981. The content of a can was evenly distributed and freely drained for 2 min on standard No. 8 circular sieve (8-in) inclined at an angle of 20 ° to facilitate draining.

Leached solids and pH of packing medium

Leached solids were determined according to the Canadian Food Inspection Agency, CFIA (2009). An aliquot (10 mL) of the canning medium from the drained weight analysis was dried at 105 °C in a hot air oven for 24 h. The solid left behind after the evaporation of moisture was weighed to represent the leached solids (g/100 g of sample). pH of canning media was determined using approved methods of the AOAC [29].

Visual color

Color of the mushrooms was determined using the Minolta color meter (CR410, Osaka-Japan), after calibrating with the reference white tile. Measurements were taken after the determination of drained weight. This was to allow for the measurement of mushrooms without interference from the canning media. Visual color of the mushrooms was described using the L* and hue angle (Eq. 1). Total Color difference (TCD) and browning index (BI) were correspondingly calculated using Eqs. 2 and 3.

$$\text{Hue angle} = \tan^{-1}(b/a), \tag{1}$$

$$TCD = \left[(L* - - L*_0)^2 + (a* - - a*_0)^2 + (b* - - b*_0)^2\right]^{1/2}, \tag{2}$$

Table 1
pH of canning medium, drained weight and leached solids of mushrooms canned in brine or oil.

Storage period	pH		Drained weight (g)		Leached solids (%)	
	Brine	Oil	Brine	Oil	Brine	Oil
Baseline	6.46±0.04[a]	5.81±0.02[c]	119.9±0.5[a]	126.4±0.8[a]	0.234±0.010[a]	0.160±0.020[a]
Month 1	6.40±0.01[b]	5.77±0.02[b]	110.6±0.8[b]	126.6±1.0[a]	0.201±0.013[b]	0.145±0.011[a]
Month 3	6.42±0.02[b]	5.59±0.03[a]	104.3±0.6[c]	125.2±0.5[a]	0.195±0.015[b]	0.151±0.020[a]
Month 6	6.39±0.02[b]	5.55±0.07[a]	103.6±0.6[c]	123.8±1.2[b]	0.197±0.009[b]	0.151±0.014[a]

Means within the same column with different letters differ significantly ($p<0.05$)

$$BI = \frac{[100(x - 0.31)]}{0.17}, \tag{3}$$

Where L*, a*, b* respectively indicate lightness or darkness, redness or greenness, yellowness or blueness of sample and $x = \frac{a^* + 1.75L^*}{5.645L^* + a^* - 3.012b^*}$

Texture

Texture Profile Analysis (TPA) was performed using a Texture Analyzer (TA.XT*plus*, Stable Microsystems, Surrey UK) with a compression cylindrical probe. Measurements were conducted on the stipes using a double bite compression cycle with the probe set to compress at a test speed of 1 mm/s during each cycle. The stipes of 10 mm in diameter measuring 8 mm long were placed upright for the compression test using a P/45 platen probe. Hardness was determined as the peak force required to compress slices of mushroom through 70% of its height. Springiness and chewiness were also derived from the Exponent software.

Enumeration of microbial counts

Ten gram (10 g) of sample was homogenized with 90 mL of sterile diluent in a stomacher and ten-fold serial dilutions of each mushroom homogenate were made. Aliquots (1 mL) of the dilutions were spread onto duplicate sterile plates for the microbial analyses. *Staphylococcus aureus* was determined by the spread plate method using Baird-Parker Agar (BP, CM 275 Oxoid Ltd, Hampshire, England.) with Egg Yolk Tellurite Emulsion (SR54) added and Blood Agar Base (BAB, CM 55 Oxoid Ltd, Hampshire, England), according to NMKL Method No. 66, [21]. *Bacillus cereus* was also determined by the spread plate method as described by NMKL No. 67, [22].

Statistical analysis

Data from the experiments were analyzed using one-way ANOVA. Means were separated using.at a 95% confidence interval using Duncan's Multiple Range Test (SPSS 17.0.1, SPSS Inc).

Results and discussions

pH is an important factor in canning as it determines sterilization temperature [7]. The probability of survival of spoilage organism during processing, or its growth in storage also largely depends on this parameter. A shift in pH may, therefore, indicate spoilage of canned foods [10]. The canned oyster mushrooms had a slightly acidic pH (Table 1), which is typical of low acid foods. At this pH, spore-forming organisms such as *Clostridium spp* may grow. Therefore, the canning operation ought to be effective enough to destroy all bacteria spores. The pH of brine reduced slightly over the study period. ANOVA showed significant differences ($F_{3,12} = 4.6$, $p<0.05$) between the starting pH and pH at the end of the six monthss. Mushrooms in oil also showed a similar trend of reduction in pH during storage. However, the decrease in pH was more pronounced (4.5% reduction) in oil compared to the reduction that occurred in brine (1.1% reduction). The formation of free fatty acids when the oil was exposed to the high sterilization temperature (121 °C) may account for the heavier decrease in pH of the vegetable oil. Stability in pH (6.4 - 6.5 and 5.6 - 5.8) of the media indicates no spoilage during storage of the canned oyster mushrooms.

Drained weight is a canning quality index and an important fill requirement [2]. This is affected by the proportion of product in the can. The drained weight of mushrooms canned in oil was higher than those canned in brine, perhaps as a result of adhering oil even after draining (more viscous and difficult to drain). Over the storage period, a slight decrease in drained weight was observed. This reduction was greater and significant ($F_{3,12} = 452.3$ $p<0.05$) after three months of storage in the case of brine. No marked decrease was observed after this period. It would appear that an isotonic condition had been attained after this period and therefore there was little or no migration of moisture from the mushroom into canning medium or vice versa. For mushrooms canned in oil, the reduction in drained weight was more prominent after six months of storage in oil. The decrease in drained weight may be ascribed to the loss of water from the mushrooms into the canning medium by osmosis [1]. Even though the mushrooms did not appear overly shriveled in the cans, it is plausible that some amount of water may have drained from the product into the canning medium. Heat treatment (blanching and

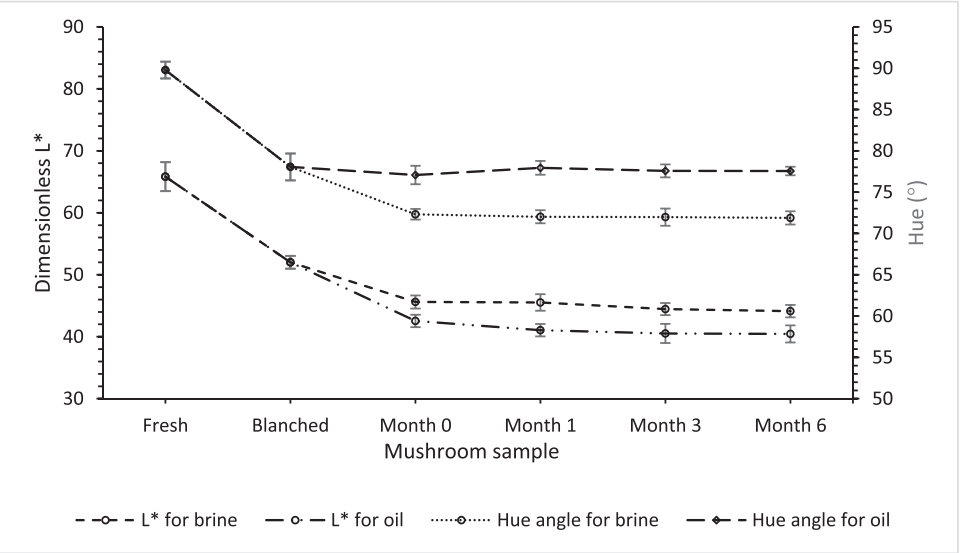

Fig. 1. Changes in L* and hue angle in fresh, blanched and canned mushrooms (in storage).

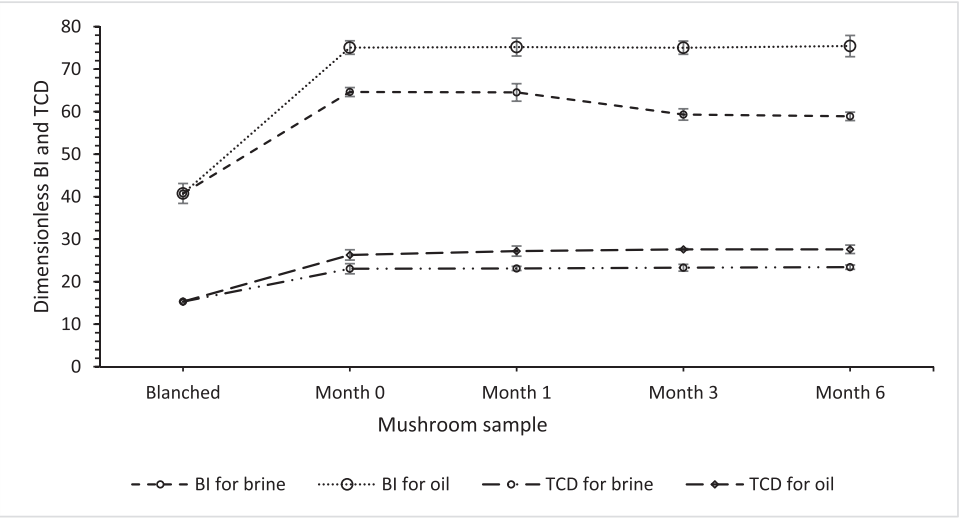

Fig. 2. Changes in BI and TCD in fresh, blanched and canned mushrooms (in storage).

sterilization) weakens cell wall firmness and facilitates the movement of water and some solids out of the mushrooms into the packing medium. In addition to moisture migration, some solids, including water-soluble single-cell protein [25], sugars and soluble fiber may also leach into the canning medium. In brine, leaching of these solids was higher over the first month of storage ($F_{3,12} = 7.0$, $p<0.05$). Between the 3rd and 6th months of storage, the amount of leached solids was largely insignificant. In the case of oil, ANOVA showed that the changes in leached solids observed was not significant ($F_{3,12} = 0.41$, $p>0.05$). Moisture migration and leaching of solids may have contributed to the changes in drained weight recorded in this study.

Processing and storage affected the appearance of the canned mushrooms. Objective color measurement of the raw and processed mushrooms showed marked changes in the color indices. For instance after steam blanching, a 20% and 13% reduction was respectively observed in L* value and hue angle of mushrooms (Fig. 1). Many of the color changes that occur in food during processing are usually attributed to browning reactions that take place during processing. These reactions may result from reactions between sugars and amino acids, the caramelization of sugar, or may be enzyme-mediated [8]. In mushrooms, browning and subsequent loss of whiteness is the result of enzymatic oxidation of polyphenols by polyphenol oxidase [27]. Although blanching has been suggested to be effective in inactivating peroxidases and preventing browning in mushrooms, in this study, some degree of darkening and significant ($F_{1,10} = 146.7$, $p<0.05$) changes in BI were observed after steam blanching (Fig. 2)

Table 2
TPA indices of fresh, blanched and canned mushrooms (in either brine or oil).

Sample	Hardness (N)		Chewiness (N)		Springiness (mm)	
	Brine	Oil	Brine	Oil	Brine	Oil
Fresh	24.3±4.7^{d}	24.3±4.7^{d}	16.1±3.1^{c}	16.1±3.1^{d}	0.95±0.02^{a}	0.95±0.02^{a}
Blanched	19.1±2.2^{c}	19.1±2.2^{c}	12.5±0.4^{b}	12.5±0.4^{c}	0.96±0.05^{a}	0.96±0.05^{a}
Month 0	8.8±0.4^{b}	7.6±0.5^{a}	3.6±0.4^{a}	4.1±0.2^{b}	0.95±0.03^{a}	0.96±0.05^{a}
Month 1	8.5±0.4^{b}	6.9±0.3^{a}	3.5±0.2^{a}	3.9±0.1^{ab}	0.95±0.05^{a}	0.93±0.04^{a}
Month 3	8.7±0.5^{b}	6.8±0.4^{a}	2.9±0.2^{a}	3.8±0.1^{ab}	0.89±0.03^{a}	0.95±0.05^{a}
Month 6	7.3±0.8^{a}	6.1±0.3^{b}	3.1±0.4^{a}	3.6±0.1^{a}	0.94±0.06^{a}	0.95±0.05^{a}

Means within the same column with different letters differ significantly ($p<0.05$)

A further decrease in L* and hue angle were recorded after sterilization of oyster mushrooms in both packing media. However, the intensity was higher in mushrooms packed in oil (Fig. 1). Oyster mushroom canned in oil appeared darker (lower L*) and more yellowish (higher hue values), compared to those canned in brine. One of the reasons for this observation is the potential of non-enzymatic browning occurring between lipid oxidation products with amines, amino acids, and proteins [28]. It is also possible that mushrooms may have picked up yellow pigments from the oil. This may explain the higher hue values recorded for "month 1", as compared to the preceding month.

Total color difference (TCD), which measures the overall difference in color between a processed sample compared to a reference (in this case, fresh mushrooms), increased significantly ($F_{2,15} = 908.8$, $p<0.05$) as a result of processing (Fig. 2). In storage, however, TCD showed no significant differences in both brine ($F_{3,20} = 0.4$, $p>0.05$) and oil ($F_{3,20} = 3.0$, $p>0.05$) between values recorded from "Month 0" through "Month 6". A similar trend was observed in BI, but here a slight dip was recorded after "Month 3". Generally, only changes were observed in the color parameters during storage, an indication that no adverse changes in product color occurred during this period. These changes may have occurred as a result of a momentary reactivation of residual polyphenol oxidase [27] causing some browning reactions and slight color changes in storage. Aside from these browning reactions, Pither [23] also maintains that dark discoloration in canned foods may occur as a result of complexes formed between chemical constituents of foods such as phenolics and tin or iron.

Texture of canned oyster mushrooms

Texture attributes of the canned mushrooms monitored over the six month storage period are presented in Table 2. TPA showed that the texture of fresh mushrooms were hard. However, this texture was lost during processing, resulting in softer and chewier mushrooms. Texture degradation during canning appears to be a one-time incident and occurs as a result of the heat treatments, i.e. blanching and sterilization. During heat treatment, the cell wall breaks down as a result of protein denaturation, solubilization of pectin, and other complex reactions which lead to softening of tissues and loss of tugor. This occurrence is responsible for the decrease in TPA parameters during the thermal processing of the mushrooms.

Notable structural changes occurred after blanching, leading to distinct softening of mushroom tissues and reduction of tugor. Indeed, blanching caused a 21.5% reduction in mushroom hardness alone. As demonstrated by Ko et al., [14] a more extensive change in texture (nearly 3-fold reduction) occurred when mushrooms were subjected to a higher temperature treatment during sterilization. This is shown by the marked differences observed in hardness and chewiness. Similar changes in hardness and other texture indices, after thermal processing of mushrooms, have been reported by Ko et al., [14] and Jaworska et al. [30] for different varieties of mushrooms, including winter mushrooms and button mushrooms. Generally, mushrooms canned in brine appeared firmer and chewier than mushrooms canned in oil. This may have been influenced by the presence of salt ions in the brine. Afoakwa et al., [2] noted an increase in hardness of green pepper when the concentration of sodium salts in the canning medium was increased. Springiness of mushrooms from the different packing media was comparable. Processing and storage had no significant effect on the springiness of mushrooms in both brine ($F_{5,18} = 1.1$, $p>0.05$) and oil ($F_{5,18} = 0.2$, $p>0.05$). This, according to Loch and Breene [31], is explained by the hydrostatic pressure established in the intercellular spaces by the presence of moisture and solutes. Apart from a slight change in hardness after six months, there were not many changes in the texture of the canned oyster mushrooms during six months of storage, irrespective of the canning media. This suggests that reactions and other physical incidences, such as changes in leached solids, which occurred may not have affected mushroom texture significantly. The change in hardness observed after six months may be attributed to further solubilization of pectic and other cell wall materials after several months of storage in brine or oil.

Microbial analyses

Microbial analyses of canned oyster mushrooms showed no microbial populations, either after canning or during storage (Table 3). As indicated by Boubaker, Eltaief and Sami [5], microbial indicators are used to assess the food safety of food products. Microbial activity in canned food may eventually lead to spoilage, with dire public health consequences. For example, the survival of spore formers such as *C. botulinum* due to inadequate thermal processing may cause cans to bloat, and this may be cause botulism when consumed. Microbial contamination of canned foods may occur as a result of poor sterilization

Table 3
Microbial analyses of canned mushrooms in brine and oil.

Storage period	*Coliform*	*Bacillus*	*C. botulinum*
Month 0	ND	ND	ND
Month 1	ND	ND	ND
Month 3	ND	ND	ND
Month 6	ND	ND	ND

ND- Not detected

procedures or through can leakage (especially, while the cans are still wet). The absence of microbial populations in both mushrooms canned in brine and mushrooms canned in oil is an indication that the canning process was effective. Sterilization at 121 °C for 30 min was adequate to attain commercial sterilization in the canned oyster mushrooms in either brine or oil.

Conclusion

Processing (blanching and canning), had significant changes in the color and textural properties of fresh oyster mushrooms. After canning, significant changes in L-value, browning index, hue angle occurred in mushrooms canned in brine or oil. Mushrooms in oil appeared darker than mushrooms in brine. Mushrooms canned in brine were firmer, and chewier, compared to mushrooms canned in oil. During storage, a significant reduction in firmness was noticed only after the sixth month of storage. The other texture parameters largely remained intact during storage for both mushrooms canned in oil and also in brine. This study has shown that, while brine provided good stability in pH and color, oil was a better medium for reducing leaching and maintaining the drained weight of canned mushrooms.

Declaration of Competing Interest

The Authors declare that we have no conflicting interest in submitting this article and publishing same in your Journal.

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