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Assessment of Microbiological Safety and Physicochemical Changes of Grey Oyster Mushroom (*Pleurotus sajor-caju*) during Storage at 4 °C and 25 °C

(Penilaian Keselamatan Mikrobiologi dan Perubahan Fizikokimia Cendawan Tiram Kelabu (*Pleurotus sajor-caju*) semasa Penyimpanan pada suhu 4 °C dan 25 °C)

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ABSTRACT

This study aimed to evaluate the microbiological and physicochemical properties of grey oyster mushroom during storage (day 0, 3, 6, 9, 12) at 4 °C and 25 °C. The microbial quality and safety analyses were aerobic plate count (APC), yeast and mould count, Escherichia coli *count,* Bacillus cereus *count, and* Listeria monocytogenes *count, while the physicochemical analyses were pH, water activity, colour, and firmness. Grey oyster mushroom stored at 4 °C showed increasing trend in all microbial counts. A similar trend was observed at 25 °C, but with higher microbial counts except for* L. monocytogenes *which had a slight reduction from 1.82 ± 1.16 at day 0 to 0.24 ± 0.34 log CFU/g at day 6. The pH of grey oyster mushroom was quite stable when stored at 4 °C (6.42 ± 0.03 at day 0 to 6.46 ± 0.21 at day 12). A decrease in pH was observed when the mushroom was stored at 25 °C (6.42 ± 0.03 at day 0 to 5.38 ± 0.93 at day 6). The Browning Index (BI) increased which indicated by the colour changes on the mushroom cap (front and back) especially at 25 °C. Firmness analysis carried out on mushroom cap and stalk showed a decreasing trend during storage, at which 25 °C displayed prominent loss of firmness in cap and stalk as compared to 4 °C. In conclusion, slower deterioration was observed in grey oyster mushroom stored at 4 °C as compared to 25 °C. This is based on lower microbial counts, and minimal changes in pH, BI, and firmness of grey oyster mushroom.*

Keywords: Ambient; grey oyster mushroom; microbiological changes; physicochemical changes; refrigeration; storage

ABSTRAK

Kajian ini bertujuan untuk menilai sifat mikrobiologi dan fizikokimia cendawan tiram kelabu semasa penyimpanan (hari 0, 3, 6, 9, 12) pada suhu 4 °C dan 25 °C. Analisis kualiti dan keselamatan mikrob yang dilakukan adalah kiraan plat aerobik (APC), kiraan yis dan kulat, kiraan Escherichia coli*, kiraan* Bacillus cereus *dan kiraan* Listeria monocytogenes*. Sementara itu, analisis fizikokimia adalah pH, aktiviti air, warna dan keutuhan. Cendawan tiram kelabu yang disimpan pada suhu 4 °C menunjukkan trend peningkatan dalam semua kiraan mikrob. Trend yang serupa diperhatikan pada 25 °C, tetapi dengan kiraan mikrob yang lebih tinggi kecuali* L. monocytogenes *yang mengalami sedikit penurunan dari 1.82 ± 1.16 pada hari 0 hingga 0.24 ± 0.34 log CFU/g pada hari ke-6. pH cendawan tiram kelabu agak stabil apabila disimpan pada suhu 4 °C (6.42 ± 0.03 pada hari ke-0 hingga 6.46 ± 0.21 pada hari ke-12). Penurunan pH diperhatikan ketika cendawan disimpan pada suhu 25 °C (6.42 ± 0.03 pada hari ke-0 hingga 5.38 ± 0.93 pada hari ke-6). Indeks Keperangan (BI) meningkat seperti yang ditunjukkan oleh perubahan warna pada topi cendawan (depan dan belakang) terutama pada suhu 25 °C. Analisis keutuhan yang dilakukan pada topi dan tangkai cendawan menunjukkan trend menurun semasa penyimpanan dengan suhu 25 °C menunjukkan kehilangan ketara dalam keutuhan topi dan tangkai berbanding pada suhu 4 °C. Sebagai kesimpulan, kerosakan yang lebih perlahan diperhatikan dalam cendawan tiram kelabu yang disimpan pada suhu 4 °C berbanding suhu 25 °C. Ini ialah berdasarkan kiraan mikrob yang lebih rendah, serta perubahan minimum pada pH, BI dan keutuhan cendawan tiram kelabu.*

Kata kunci: Cendawan tiram kelabu; penyejukan; penyimpanan; perubahan fizikokimia; perubahan mikrobiologi; suasana

Introduction

Grey oyster mushroom or scientifically known as *Pleurotus sajor-caju* is one of the 17 major mushroom varieties which can be grown in Malaysia (Mat Amin et al. 2013; Samsudin & Abdullah 2019). Mushroom production value was around RM100 million in the year 2014, and the production value mainly comes from the cultivation of grey oyster mushroom which represents 90.89 per cent

of the total cultivated mushroom in Malaysia (Rosmiza et al. 2016). Grey oyster mushroom is being cultivated and commercialised in the lowlands of Malaysia (Amin & Harun 2015) due to the favourable tropical climatic conditions. Its cultivation is relatively simple with low production costs, thus leading it to being available all year-round. Due to its unique taste (Ang & Ismail-Fitry), this mushroom is high in consumption and demand among Malaysians. Generally, mushrooms have high amount of proteins, essential amino acids, carbohydrates, minerals, vitamins, and low calorie (Wakchaure 2011). Most edible mushrooms are known to contain protein value of 14 to 19 per cent based on dry weight, which is relatively higher than the protein contents of vegetables; thus, they could be a promising alternative to meat (Alexander 2013; Amuneke et al. 2011; Bashir et al. 2014; Jonathan et al. 2012; Rosmiza et al. 2016).

Despite all the nutritional advantages, fresh mushrooms have a short shelf life of three to four days at room/ambient temperature. The short shelf life is due to the absence of cuticle to protect them from both physical damage and microbial attack, as well as having high respiration rate and (Villaescusa & Gil 2003). Due to these factors, mushrooms cannot be completely sealed in a pack as they will decay due to the reaction of browning, wilting, liquefaction, texture loss, aroma loss, and flavour loss (Kamal et al. 2015). The decay might also arise from bacterial contamination on the tissues of the mushrooms. In contrast, browning might be caused by a synergistic combination of microbial and auto-enzymatic reaction on the tissues of the mushrooms (Kamal et al. 2015).

A study on fresh oyster mushroom contamination in Dhaka, Bangladesh found that some of the mushrooms contained coliform, faecal coliform, *E. coli*, and *Salmonella* spp. with the highest count reported on standard plate count was 8.9 log CFU/g (Mustafa Kamal et al. 2010). Kim et al. (2016) observed that shiitake mushrooms cultivated in Virginia, USA had aerobic mesophilic count of 7.5 ± 1.1 log CFU/g, yeast and mould count of 6.0 ± 0.3 log CFU/g, coliform count of 1.9 ± 1.1 log MPN/g, and were also detected with *Listeria* spp. Fresh grey oyster mushroom could contain spoilage and pathogenic microorganisms due to cross-contamination from its growth substrate, and during postharvest handling. Furthermore, keeping the grey oyster mushroom at different temperatures could provide various microbial profiles and physicochemical changes. Therefore, the objective of this study was to evaluate the microbiological quality and safety, and physicochemical properties of grey oyster mushroom during storage at refrigeration (4 °C) and ambient (25 °C) temperatures.

Materials and Methods

Sample collection and experimental design

Fresh grey oyster mushroom was purchased from the Mushroom Unit, Crop Division, University Agriculture Park (UAP), Universiti Putra Malaysia (UPM), Serdang, Selangor, Malaysia on the day it was harvested. The samples were packed in a clear polypropylene bag, and heat-sealed. The packaged mushrooms were brought to the laboratory in a cold box, and immediately kept at 4 °C and 25 °C for 12 days. The samples were analysed for microbiological and physicochemical properties at three-day intervals during storage (day 0, 3, 6, 9, 12). The experiments were carried out in triplicates.

Microbiological analyses

Sample of grey oyster mushroom was aseptically weighed for 50 g, and diluted with 450 mL of sterile peptone water diluent before being homogenised for 2 min. This yielded a 10^{-1} dilution. Then, 1 mL of the dilution was serially diluted into 9 mL of similar diluent until 10^{-6}. All dilution factors (10^{-1} to 10^{-6}) were vortexed. Next, 100 µL from each dilution factor was spread onto plate count agar (PCA) (Oxoid, Hampshire, UK) for aerobic plate count, potato dextrose agar (PDA) (Oxoid, Hampshire, UK) for yeast and mould count, eosin methylene blue (EMB) for *E. coli* count, *Bacillus* agar (Oxoid, Hampshire, UK) for *B. cereus* count, and PALCAM agar with PALCAM Selective Supplement (SR0150) (Oxoid, Hampshire, UK) for *L. monocytogenes* count. Inoculated agar plates were incubated at 37 °C for 48 h. For selective agar, colonies were enumerated based on the following characteristics; for *E. coli*, purple-coloured colonies with green metallic sheen; for *L. monocytogenes*, dimpled brown/black coloured colonies with black halo; and for *B. cereus*, peacock blue colonies with precipitate and peacock blue medium were observed. Microbial growth was reported as logarithm numbers of colony-forming unit per gram ($\log_{10}$ CFU/g) of samples.

pH and water activity analyses

pH analysis was carried out by diluting 50 g of sample into 450 mL of peptone water diluent. Peptone water is known to have a pH of 7.2 ± 0.2 (Thermo Scientific 2017). The pH meter was calibrated with buffers of pH 4.01, 9.21, and 7.00 (Mettler Toledo, USA), and the measurements of pH were carried out.

Water activity analysis was carried out using AquaLab Series 3 Water Activity Analyzer (Decagon Devices, USA). A small portion, approximately 5 g of the

sample, was placed onto the measuring container before being loaded into the measuring chamber, and sealed for the measurement.

COLOUR ANALYSIS

The colour analysis of the grey oyster mushroom as a function of storage time was carried out using a handheld colorimeter (Konica Minolta CR-410, Japan). The instrument was first calibrated against a white calibration plate prior to colour measurement. The colour measurement of the samples was carried out by placing measuring head flat on the front and back caps of the grey oyster mushroom. On the other hand, the browning index (BI) of the grey oyster mushroom as a function of storage time was calculated according to L^* (light to dark), a^* (red to green), and b^* (yellow to blue) using the following formula (Kortei et al. 2015):

$$\text{Browning Index (B.I)} = [100\ (x - 0.31)] / 0.17$$
$$\text{where; } x = (a^* + 1.75\ L^*) / (5.645\ L^* + a^* - 3.012\ b^*)$$

FIRMNESS ANALYSIS

A TA.XT2i Texture Analyser (Stable Micro Systems, UK) was used to measure the firmness properties of grey oyster mushroom. Penetration evaluation was carried out using a cylindrical probe with a diameter of 2 mm, and penetration of mushroom cap and stalk at depth of 10 and 15 mm, respectively, with pre-test, test and post-test speed of 5.0 mm/s (Lagnika et al. 2013).

STATISTICAL ANALYSIS

All experiments were done in triplicate, and results were expressed as mean ± SD (standard deviation). Statistical analyses were carried out using Minitab 19 (Minitab Inc., State College, PA, USA). One-Way Analysis of variance (ANOVA) with Tukey multiple comparison test were applied to find out the significant differences within the means of each microbial populations, and the means of each physicochemical properties between storage time (days). Significant difference was taken at $p < 0.05$.

RESULTS AND DISCUSSION

AEROBIC PLATE COUNT (APC) AND YEAST AND MOULD COUNT (YMC) IN GREY OYSTER MUSHROOM

Aerobic plate count (APC) indicates the level of viable aerobic bacteria in a product. The APC of grey oyster mushroom during storage at 4 and 25 °C is presented in Table 1 which shows that it increased with storage time from day 0 to day 12 for both storage temperatures. Grey oyster mushroom stored at 4 °C had a significant increase ($p < 0.05$) in APC on day 3, up to 7.45 log CFU/g from the initial APC of 3.87 log CFU/g. However, the APC for day 6, 9 and 12 significantly decreased to an average of 4.00 log CFU/g. The fluctuation in APC could be due to the effect of mushroom respiration in which it takes up oxygen and produces carbon dioxide (Iqbal et al. 2009). In a micro-environment (i.e. in food packaging) that contains less oxygen than normal air, spoilage is slowed down. It has been reported that another species of oyster mushroom (*P. ostreatus*) packed in low-density polyethylene plastic also showed fluctuation in the percentage of O_2 and CO_2 contents following storage at 4 °C for 11 days (Sapata et al. 2009).

Contradicting trend was observed when grey oyster mushroom was stored at 25 °C, during which the APC steadily increased over the 12 days of storage. The APC was enumerated until day 6 with 7.10 log CFU/g, and grey oyster mushroom was considered spoiled due to mould growth and fishy smell detected on day 9 and 12. Therefore, all analyses for samples at 25 °C could only be carried out until day 6. Mesophilic microorganisms can survive at temperatures between 10 °C and 50 °C with an optimum of around 20 °C to 37 °C. This group of mesophiles is also known to cause rot and fermentation which are major manifestations of food spoilage (Jay et al. 2008). In a previous study, Venturini et al. (2011) found that the microbial count of mesophilic microorganisms detected in another species of oyster mushroom (*P. ostreatus*) was 5.30 ± 0.6 log CFU/g at day 0. The count reported was slightly higher than the count in the current study; this could be due to the samples purchased from retail markets across Zaragoza, Spain, and no temperature storage was controlled.

Table 1 also shows the yeast and mould count at 4 °C and 25 °C. There was also an increasing trend throughout the storage at both storage temperatures; rather similar to APC. Yeasts and moulds have the ability to grow under broad temperature range (10 °C to 35 °C), with a few species capable of growth below or above this range. Both yeasts and moulds cause various degrees of deterioration and decomposition of foods. They can invade and colonise any type of food at any time throughout the supply chain; they invade crops such as grains, nuts, beans, and fruits in fields before harvesting and during storage (Hitchins et al. 1998).

TABLE 1. Total plate count and yeast and mould count in grey oyster mushroom during storage at 4 °C and 25 °C

Days	4 °C		25 °C	
	Total plate count (Log CFU/g)	Yeast and mould count (Log CFU/g)	Total plate count (Log CFU/g)	Yeast and mould count (Log CFU/g)
0	3.87 ± 1.06^{B}	4.73 ± 0.03^{C}	3.87 ± 1.06^{B}	4.73 ± 0.03^{B}
3	7.45 ± 0.00^{A}	7.37 ± 0.00^{A}	5.02 ± 1.69^{AB}	5.86 ± 0.44^{A}
6	4.96 ± 0.23^{B}	5.73 ± 0.13^{B}	7.10 ± 0.69^{A}	6.84 ± 0.99^{A}
9	4.34 ± 0.18^{B}	5.13 ± 0.86^{BC}	n.a.	n.a.
12	4.12 ± 0.68^{B}	5.30 ± 0.67^{BC}	n.a.	n.a.

Data are mean ± SD of triplicate ($n = 3$). Means within a column that do not share similar letter are significantly different ($p < 0.05$). n.a.: data not available due to sample spoilage during storage.

Escherichia coli COUNT IN GREY OYSTER MUSHROOM

Escherichia coli is a rod-shaped Gram-negative bacterium, and an indicator microorganism that reflects poor level of hygiene and sanitation of food processing. *E. coli* count in the grey oyster mushroom is presented in Table 2. The initial count of *E. coli* at both temperatures was 3.37 ± 0.18 log CFU/g. An increase in storage time led to an increase in *E. coli* count to 3.62 ± 1.56 log CFU/g (on day 12 at 4 °C) and 5.44 ± 2.72 log CFU/g (on day 6 at 25 °C). Similar trend has been reported during the storage of *P. ostreatus* in various polymeric packaging in which the coliform count increased from 5.53 to 8.52 log CFU/g from day 0 to day 11, respectively (Sapata et al. 2009). Another study on fresh, processed, and preserved mushrooms varieties collected around Dhaka City found that 100 g oyster mushroom packed in polyethylene bags were positive for *E. coli* (Mustafa Kamal et al. 2010). Although *E. coli* does not thrive over a long period on plant surfaces, and is only associated with recent water contamination, to date, there is no regulation set on its presence on unprocessed fresh fruits and vegetables (Monaghan 2010).

TABLE 2. *Escherichia coli* count in grey oyster mushroom during storage at 4 °C and 25 °C

Days	*Escherichia coli* count (Log CFU/g)	
	4 °C	25 °C
0	3.37 ± 0.18^{B}	3.37 ± 0.18^{A}
3	3.57 ± 0.42^{B}	5.74 ± 2.47^{A}
6	4.72 ± 0.16^{A}	5.44 ± 2.72^{A}
9	2.34 ± 3.30^{AB}	n.a.
12	3.62 ± 1.56^{AB}	n.a.

Data are mean ± SD of triplicate ($n = 3$). Means within a column that do not share similar letter are significantly different ($p < 0.05$). n.a.: data not available due to sample spoilage during storage

PRESUMPTIVE *Bacillus cereus* AND *Listeria monocytogenes* COUNTS IN GREY OYSTER MUSHROOM

Bacillus cereus was detected in grey oyster mushroom at both storage temperatures (Table 3). Grey oyster mushroom stored at 4 °C showed an increase in presumptive *B. cereus* count from 0.50 ± 0.71 log CFU/g at day 0 to 1.67 ± 2.37 at day 12. This trend was similar for sample stored at 25 °C, where the count increased

from 0.50 ± 0.71 (day 0) to 2.72 ± 3.84 log CFU/g (day 6). *Bacillus cereus* is readily available in the environment, including organic matter such as decaying vegetables, and also in the gut of invertebrates (Bottone 2010). Previously, *B. cereus* was detected in fresh whole and sliced shiitake mushroom, both at 1.0 log CFU/g (Kim et al. 2016). The concern with *B. cereus* is the possibility of cereulide toxin production. Cereulide is often produced under favourable conditions such as in food with high starches, carbohydrates, vitamins, and trace minerals, and under physiological conditions such as neutral pH, and intermediate to high water activity (Messelhausser et al. 2014).

Table 3 also presents the presumptive *L. monocytogenes* count in grey oyster mushroom. Grey oyster mushroom stored at 4 °C showed an increase in the presumptive *L. monocytogenes* count from 1.89 ± 1.08 log CFU/g at day 0 to 2.09 ± 0.69 log CFU/g at day 12. Nevertheless, there was a drop in the presumptive *L. monocytogenes* count at 25 °C in which the initial value of 1.82 ± 1.16 log CFU/g decreased to 0.24 ± 0.34 log CFU/g at day 6. This could be due to the nature of this bacterium which grow at a temperature between -1.5 and 45 °C, and has tolerant towards acidic environment. However, at elevated temperature, this bacterium is more sensitive towards the acidic environment Food Standards Australia New Zealand (2013). This can be proven in Table 4, where the final pH of the sample at 4 and 25 °C were 6.46 ± 0.21 and 5.38 ± 0.93, respectively. Based on a previous study on *L. monocytogenes* count in button mushroom, it was found that the amount of the bacterium increased to log 1 and log 2 at 4 °C and 10 °C storage within two days, respectively. After two days, the bacterial count remained constant until day 8, after which a decline in the count to around 1 to 2 log units reduction was observed due to the presence of competitive microflora (Gonzalez-Fandos et al. 2001). Additionally, according to LaBorde (2017), some of the substrates for mushroom compost/spawning is often derived from manure or manure-based component, which might harbour various pathogens. This could explain the presence of *L. monocytogenes* in this study.

TABLE 3. Presumptive *Bacillus cereus* and *Listeria monocytogenes* counts in grey oyster mushroom during storage at 4 °C and 25 °C

Days	4 °C		25 °C	
	B. cereus (Log CFU/g)	*L. monocytogenes* (Log CFU/g)	*B. cereus* (Log CFU/g)	*L. monocytogenes* (Log CFU/g)
0	0.50 ± 0.71^{B}	1.89 ± 1.08^{A}	0.50 ± 0.71^{A}	1.82 ± 1.16^{A}
3	2.03 ± 0.43^{A}	1.88 ± 0.82^{A}	0.76 ± 1.08^{A}	2.91 ± 2.39^{A}
6	1.84 ± 2.61^{AB}	1.52 ± 0.06^{A}	2.72 ± 3.84^{A}	0.24 ± 0.34^{B}
9	2.37 ± 3.35^{AB}	1.19 ± 2.36^{A}	n.a	n.a
12	1.67 ± 2.37^{AB}	2.09 ± 0.69^{A}	n.a	n.a

Data are mean ± SD of triplicate (n = 3). Means within a column that do not share similar letter are significantly different ($p < 0.05$). n.a.: data not available due to sample spoilage during storage

pH AND WATER ACTIVITY OF GREY OYSTER MUSHROOM

pH is a parameter that depicts the acidity/alkalinity of a product. The pH of grey oyster mushroom at 4 °C storage from day 0 to day 12 ranged from pH 6.30 ± 0.17 to 6.46 ± 0.21 (Table 4). A research carried out by Roy et al. (2015) found that the pH value of fresh oyster mushroom (*P. ostreatus*) was pH 6.14. For grey oyster mushroom stored at 25 °C, the pH decreased from pH 6.42 ± 0.03 to 5.38 ± 0.93 from day 0 to day 6 of storage. This could be related to the breakdown of sugar to produce acids; at ambient temperature, this breakdown could be accelerated. Moreover, respiration occurs faster when storage temperature is high, which also leads to the production of acid (Wills et al. 1989). Low-temperature storage could be effective in slowing down the rate of respiration and senescence of fresh fruits and vegetables.

The water activity of grey oyster mushroom was consistent (0.98 a_w) throughout the storage at both 4 °C and 25 °C (Table 4). According to Fernandez-Salguero et al. (1993), water activity above 0.95 a_w will cause bacteria to colonise the food, whereas, water activity below 0.95 a_w will cause the yeasts and moulds to predominate. Most fresh fruits and vegetables has the water activity of 0.97 and above.

TABLE 4. pH and water activity of grey oyster mushroom during storage at 4 °C and 25 °C

Days	4 °C		25 °C	
	pH	Water activity	pH	Water activity
0	6.42 ± 0.03^{A}	0.98 ± 0.01^{A}	6.42 ± 0.03^{A}	0.98 ± 0.01^{A}
3	6.30 ± 0.17^{A}	0.98 ± 0.00^{A}	5.91 ± 0.71^{AB}	0.98 ± 0.01^{A}
6	6.37 ± 0.01^{A}	0.98 ± 0.00^{A}	5.38 ± 0.93^{B}	0.98 ± 0.00^{A}
9	6.43 ± 0.27^{A}	0.98 ± 0.00^{A}	n.a	n.a
12	6.46 ± 0.21^{A}	0.98 ± 0.00^{A}	n.a	n.a

Data are mean ± SD of triplicate (n = 3). Means within a column that do not share similar letter are significantly different (p < 0.05). n.a.: data not available due to sample spoilage during storage

COLOUR MEASUREMENT OF GREY OYSTER MUSHROOM

Based on Table 5, the front cap of the grey oyster mushroom showed an increase in the browning index (BI) from day 0 (29.35) to day 12 (50.47) when stored at 4 °C. Similar trend was also observed in the BI of the back cap at the same storage temperature. According to Xiao et al. (2011), suitable conditions in packaging permeability and product surface could prevent gas respiration which causes severe browning in mushrooms. Moreover, browning could also occur from microbial action and enzymatic reaction within the mushroom tissues (Kamal et al. 2015). Shock, cutting damage, and loss of firmness could activate browning of mushrooms, thus leading to adverse changes in their organoleptic and nutritional values (Toivonen & Brummell 2008). For storage of grey oyster mushroom at 25 °C (Table 6), the BI of front cap showed an increase from day 0 (40.58) to day 6 (60.42). Back cap also showed an increase of BI from day 0 (24.34) to day 6 (43.09).

Tables 5 and 6 also show the **L*, **a*, and **b* values of mushroom caps (front and back) after 12 storage at 4 °C and 25 °C, respectively. According to Roshita et al. (2017), cap of fresh grey oyster mushroom had the **L, *a*, and **b* values of 52.89 ± 8.01, 7.62 ± 0.62, and 10.57 ± 1.94, respectively. Almost similarly, Firdhaus et al. (2015) reported that fresh oyster mushroom showed the values of 59.70 ± 3.01, 8.54 ± 0.36, and 12.34 ± 2.00 for **L, *a* and **b* values, respectively. The difference between those studies and this study might be due to the effect of storage.

TABLE 5. CIE *Lab* and Browning Index of grey oyster mushroom during storage at 4 °C

Days	Front Cap				Back Cap			
	**L*	**a*	**b*	Browning Index	**L*	**a*	**b*	Browning Index
0	76.59 ± 1.18^{A}	6.72 ± 0.41^{ABC}	15.67 ± 0.89^{B}	29.35	75.59 ± 1.18^{A}	3.18 ± 0.21^{A}	14.73 ± 0.73^{C}	24.34
3	77.92 ± 1.61^{A}	6.34 ± 0.70^{ABC}	17.08 ± 1.24^{AB}	30.29	77.92 ± 1.61^{A}	2.22 ± 0.08^{B}	16.86 ± 3.27^{ABC}	25.96
6	70.09 ± 9.08^{AB}	5.628 ± 0.70^{C}	18.43 ± 1.29^{AB}	35.88	75.52 ± 1.40^{A}	3.44 ± 0.49^{A}	20.47 ± 2.38^{AB}	34.34
9	62.58 ± 0.00^{AB}	6.69 ± 0.00^{B}	19.02 ± 0.00^{AB}	43.50	76.83 ± 0.00^{A}	3.10 ± 0.00^{A}	20.62 ± 0.00^{A}	33.59
12	56.69 ± 0.00^{B}	7.04 ± 0.00^{A}	19.46 ± 0.00^{A}	50.47	71.35 ± 0.00^{B}	3.16 ± 0.00^{A}	19.16 ± 0.00^{B}	33.92

Data are mean ± SD of triplicate (n = 3). Means within a column that do not share similar letter are significantly different (p < 0.05)

TABLE 6. CIE *Lab* and Browning Index of grey oyster mushroom during storage at 25 °C

Days	Front Cap				Back Cap			
	*L	*a	*b	Browning Index	*L	*a	*b	Browning Index
0	76.59 ± 1.18^{A}	6.72 ± 0.41^{A}	15.67 ± 0.89^{B}	29.35	75.59 ± 1.18^{A}	3.18 ± 0.21^{A}	14.73 ± 0.73^{C}	24.34
3	60.30 ± 2.17^{B}	5.94 ± 0.51^{A}	21.08 ± 0.93^{A}	49.54	72.28 ± 1.03^{B}	2.76 ± 0.04^{B}	18.15 ± 0.50^{B}	31.15
6	49.61 ± 1.08^{C}	6.63 ± 0.37^{A}	20.00 ± 0.89^{A}	60.42	63.22 ± 5.64^{C}	2.03 ± 0.00^{C}	21.56 ± 1.83^{A}	43.09

Data are mean ± SD of triplicate (n = 3). Means within a column that do not share similar letter are significantly different (p < 0.05)

FIRMNESS PROFILE OF GREY OYSTER MUSHROOM

Texture analysis of grey oyster mushroom was carried out on the cap and the stalk to measure its firmness. It was found that the firmness of the cap and stalk significantly decreased throughout the storage (Figure 1). A study conducted by Lagnika et al. (2013) on the shelf life of white mushroom (*Agaricus bisporus*) with the treatment of ultrasound and high-pressure argon found that all the treated and control samples showed a reduction in firmness (N) after nine days of storage at 4 °C, as observed in this study. At 25 °C, the firmness of the grey oyster mushroom cap and stalk exhibited similar decreasing trend (cap: 1.86 to 0.95 N; stalk: 5.71 to 3.66 N; Figure 2) to that observed at 4 °C. According to Firdhaus et al. (2015), fresh grey oyster mushroom treated with different sound intensities had the firmness of between 117.31 ± 43.93 g and 107.24 ± 59.60 g. In this study, higher firmness of fresh (day 0) grey oyster mushroom cap was observed (1.86 ± 0.17 N or 189.85 ± 17.32 g).

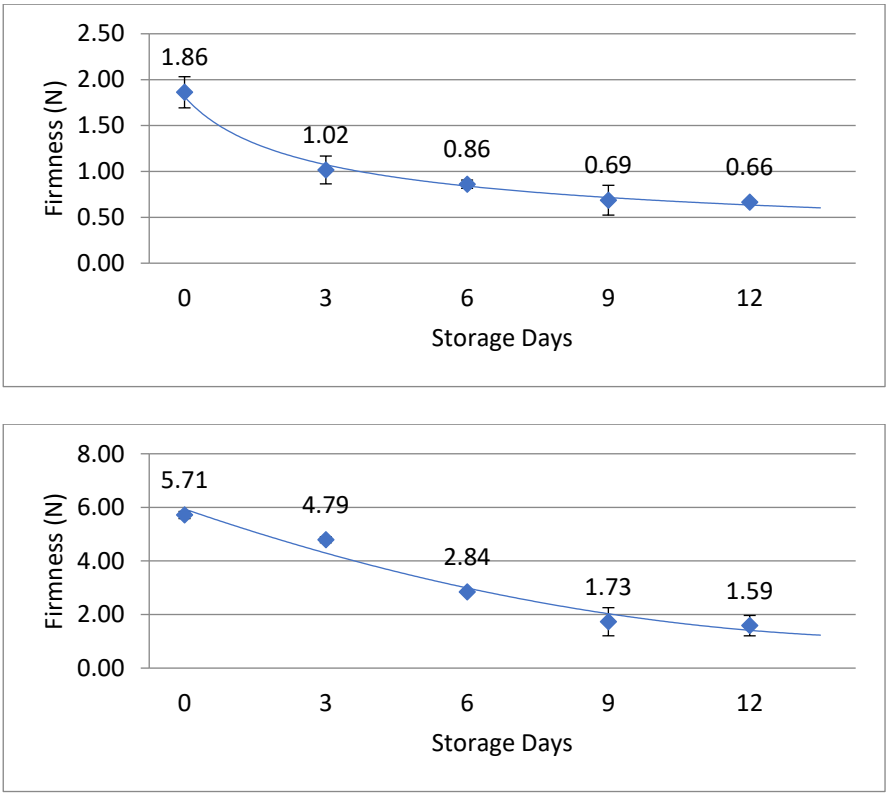

FIGURE 1. Firmness of grey oyster mushroom cap (a) and stalk (b) during storage at 4 °C

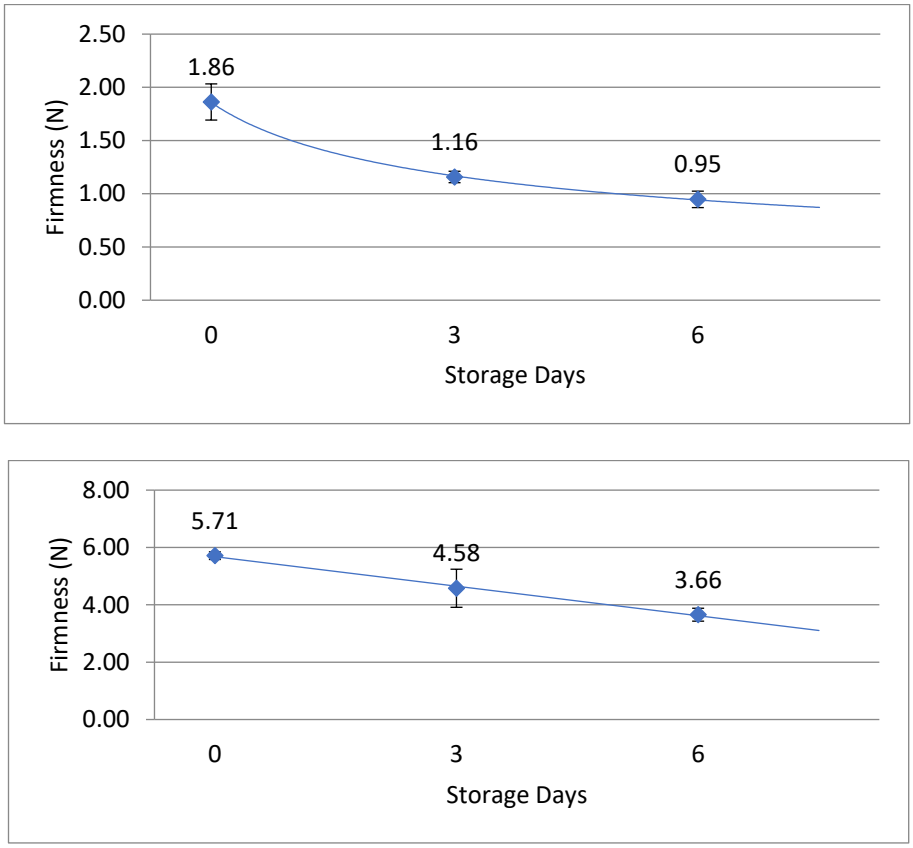

FIGURE 2. Firmness of grey oyster mushroom cap (a) and stalk (b) during storage at 25 °C

CONCLUSION

This study analysed the effect of storage temperatures (refrigeration, 4 °C; ambient, 25 °C) on the microbiological quality and safety, and physicochemical properties of grey oyster mushroom. Lower temperature (4 °C) was found able to delay unfavourable changes in the microbial counts where the values of total plate count and yeast and mould count exceeded log 6.00 CFU/g only on day 6, as compared to storage at 25 °C. For physicochemical changes, grey oyster mushroom showed less adverse changes when stored at 4 °C as compared to 25 °C; lower browning index (BI), and minimal pH and firmness reduction were observed. The water activity of grey oyster mushroom remained constant during storage at both temperatures. Therefore, storage and retail of grey oyster mushroom at lower temperature (4 °C) is recommended.

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