UNIVERSITI PUTRA MALAYSIA

EVALUATION OF MATURITY STAGE, POSTHARVEST STORAGE TEMPERATURE AND PACKAGING SYSTEM TOWARDS MAXIMISING QUALITY RETENTION OF STRAW MUSHROOM [*Volvariella volvacea* (Bul.) Singer]

NUR SAKINAH BINTI MOHD JOHA

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By

NUR SAKINAH BINTI MOHD JOHA

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATION

Special dedications to my beloved parents, siblings, family members, supervisors, and friends for their endless support, sacrifices, understandings, motivation, advice and encouragement.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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June 2019

Chairperson: Azizah Misran, PhD
Faculty: Agriculture

Volvariella volvacea, also known as straw mushroom is edible. It has attracted growing attention in Malaysia due to short cropping duration and provides distinct flavour and pleasant taste. However, this mushroom is highly perishable and has very short shelf life within 1-2 days under ambient temperature. The harvesting time and maturity of *V. volavacea* are important factors to maintain the quality of the mushroom. As the succeeding stages that follow the immature stage was particularly fast, farmers usually collected both immature and mature stage at harvest. Thus the objective of the first experiment was to evaluate the quality, antioxidant activity, and health risk assessment of *V. volvacea* at both stages. The mushrooms was cultivated on composted EFB and harvested after a week at immature (button stage) and mature (veil open stage). Button stage mushroom showed significantly higher firmness, and higher antioxidant activity with lower IC_{50} of DPPH. In addition, button stage provides higher content of glutamic acid. However, both stages were within safety limit dietary intake from heavy metals. Thus, based on the results of the first experiment, button stage was further selected for the second experiment.

The objective of the second experiment was to determine the postharvest qualities and antioxidant activity at different storage temperatures (10, 15 ºC, and room temperature (RT)) and storage durations (0, 2, 4, 6 and 8 days). The *V. volvacea* was cultivated according to Experiment 1 and the button stage were harvested for storage in perforated polyethylene (PE) plastic films. *Volvariella volvacea* stored at 15 °C showed significantly lowest in the percentage of weight loss, no veil opening, retains higher firmness, inhibits browning and PPO enzyme activity for about 6 days. The *V. volvacea* stored at 10 ºC showed chilling injury symptoms and loss its postharvest quality. However, there was a sharp drop of DPPH activity when stored at RT. The

tissue ultrastructure of *V. volvacea* at 15 ºC showed no major changes as compared to 10 ºC and RT where there were tissue shrinkage and bacterial contamination. Thus the mushrooms were best stored at 15 ºC for the next experiment.

The experiment was then expanded to the third objective which was to examine the optimum packaging systems (perforation, PVC film wrap, vacuum and control) applied to *V. volvacea* at different storage durations (0, 2, 4, 6 and 8 days) and stored at 15 ºC. The cultivation and harvesting method was conducted as previous. The mushrooms were packed in 4 different packaging systems. PVC film was shown to maintain significantly higher firmness, lower weight loss, high DPPH radical scavenging activity, lower browning degree and PPO enzyme activity compared to other packaging. Furthermore, there was less damages and shrinkage of ultrastructure tissue when stored in PVC film packaging showed. Overall, button stage of *V. volvacea* were best stored at 15 °C storage temperature in PVC film packaging system which could retain their quality throughout 6 days storage periods and extend their shelf life.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENILAIAN TERHADAP PERINGKAT KEMATANGAN, SUHU SIMPANAN DAN SISTEM PEMBUNGKUSAN LEPAS TUAI UNTUK PENGEKALAN KUALITI CENDAWAN JERAMI [*Volvariella volvacea* (Bul.) Singer]

Oleh

NUR SAKINAH BINTI MOHD JOHA

Jun 2019

Pengerusi: Azizah Misran, PhD
Fakulti: Pertanian

Volvariella volvacea adalah sejenis cendawan yang dikenali sebagai cendawan jerami dan boleh dimakan. Perhatian terhadap cendawan ini semakin berkembang di Malaysia disebabkan tempoh penanaman yang singkat dan cendawan ini memberikan rasa yang berbeza dan lazat. Walau bagaimanapun, cendawan ini sangat mudah rosak dan mempunyai jangka hayat yang sangat pendek di antara 1-2 hari pada suhu bilik. Tahap kematangan dan penuaian *V. volavacea* adalah satu parameter penting untuk menghasilkan cendawan yang berkualiti tinggi. Apabila proses kematangan berlaku dengan cepat, pengusaha biasanya mengutip cendawan jerami yang belum matang dan matang ketika proses penuaian. Oleh itu objektif eksperimen pertama adalah untuk menilai kualiti, aktiviti antioksidan, dan penilaian risiko kesihatan *V. volvacea* pada kedua-dua peringkat kematangan. Cendawan ini ditanam di atas kompos tandan buah kosong dan dituai selepas seminggu ketika belum matang (peringkat butang) dan matang (peringkat volva terbuka). Cendawan peringkat butang menunjukkan kekerasan, aktiviti antioksidan yang lebih tinggi, dengan IC_{50} DPPH yang rendah. Di samping itu, peringkat butang mempunyai kandungan asid glutamat yang lebih tinggi. Walaubagaimanapun, kedua-dua peringkat berada dalam had pengambilan makanan yang selamat dari logam berat. Oleh itu, berdasarkan hasil kajian eksperimen pertama, peringkat butang dipilih untuk menjalankan eksperimen kedua.

Objektif eksperimen kedua adalah bagi menentukan kualiti lepas tuai dan aktiviti antioksidan pada suhu penyimpanan yang berbeza (10, 15 ºC, dan suhu bilik (RT)) dan tempoh penyimpanan (0, 2, 4, 6 dan 8 hari). *Volvariella Volvacea* ditanam seperti Eksperimen 1 dan peringkat butang dituai dan disimpan dalam plastik polietilena (PE) yang berlubang. *Volvariella volvacea* yang disimpan pada suhu 15 °C menunjukkan kehilangan berat paling rendah, tiada pembukaan volva, mengekalkan kekerasan yang lebih tinggi, menghalang kadar pemerangan dan enzim PPO. *Volvariella volvacea* yang

disimpan pada 10 ºC menunjukkan gejala kecederaan dingin dan kehilangan kualiti lepas tuai. Walaubagaimanapun, terdapat penurunan mendadak aktiviti DPPH apabila disimpan pada suhu bilik. Tisu ultrastruktur *V. volvacea* pada 15 ºC tidak menunjukkan perubahan besar berbanding 10 ºC dan suhu bilik di mana terdapat pengecutan tisu dan pencemaran bakteria. Oleh itu, cendawan akan disimpan pada suhu 15 ºC untuk eksperimen seterusnya.

Eksperimen seterusnya diperluaskan kepada objektif ketiga iaitu untuk menentukan sistem pembungkusan optimum (perforation, bungkus filem PVC, vakum dan kawalan) yang digunakan untuk *V. volvacea* pada tempoh penyimpanan yang berlainan (0, 2, 4, 6 dan 8 hari) dan disimpan pada suhu 15 ºC. Kaedah penanaman dan penuaian telah dijalankan seperti sebelumnya. Cendawan telah dibungkus menggunakan 4 sistem pembungkusan yang berbeza. Filem PVC telah menunjukkan pengekalan kekerasan yang lebih tinggi, kehilangan berat yang lebih rendah, aktiviti pemerangkapan radikal DPPH yang tinggi, tahap pemerangan dan aktiviti enzim PPO yang rendah berbanding pembungkusan lain. Selain itu, terdapat kurang kerosakan dan pengecutan tisu ultrastruktur apabila disimpan dalam pembungkusan filem PVC. Secara keseluruhan, peringkat butang *V. volvacea* merupakan tahap paling sesuai dituai dan disimpan pada suhu 15 °C menggunakan sistem pembungkusan filem PVC bagi mengekalkan kualiti sepanjang tempoh penyimpanan dan seterusnya melanjutkan jangka hayat cendawan tersebut sehingga hari keenam.

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Sakinah Joha

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree Master of Science. The members of Supervisory Committee were as follows:

Azizah binti Misran, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Chairperson)

Mahmud bin Tengku Muda Mohamed, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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Signature: ____________________________________
Name of Chairman of
Supervisory Committee: Azizah binti Misran, PhD

Signature: ____________________________________
Name of Member of
Supervisory Committee: Mahmud bin Tengku Muda Mohamed, PhD

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et al.	and others
%	Percentage
ºC	Degree celcius
EDI	Estimated daily intake
THQ	Target hazard quotient
MAP	Modified atmosphere packaging
kg	kilogram
g	gram
cm	centimetre
LDPE	Low-density polyethylene
PP	Polypropylene
SEM	Scanning electron microscope
PPO	Polyphenol oxidase
µg	microgram
GAE	Gallic acid equivalent
mg	milligram
QE	Quercetin
DPPH	2,2-Diphenyl-1-Picrylhydrazyl
Fe	Iron
Cu	Copper
Zn	Zinc
Pb	Lead
Cd	Cadmium
Hg	Mercury
Ni	Nickel
FAO	Food and Agriculture Organization
WHO	World Health Organisation
ANOVA	Analysis of variance
PE	polyethylene
SEM	Scanning electron microscope
$NaCO_3$	Sodium carbonate
$NaNO_3$	Sodium nitrate
$AlCl_3$	Aluminium chloride
NaOH	Sodium hydroxide
LSD	Least significant difference
N	Newton
RT	Room temperature
U/mg FW	Unit per milligram fresh weight
RH	Relative humidity
PLW	Physiological loss in weight
F	Firmness
VO	Veil opening
TPC	Total phenolic contents
TFC	Total flavonoid contents
BD	Browning degree

CHAPTER 1

GENERAL INTRODUCTION

Edible mushroom contributes to large income and became economically important industrial commodities (Kukura *et al*., 1998). These include production for whole food, fermented beverages, food additives, antibiotics, probiotics, pharmaceutical industries, biofuels, enzymes, and some bioactive compounds such as vitamins, fatty acids and sterols (Gan *et al*., 2013; Manzi *et al*., 1999). Mushroom is widely cultivated all over the world (Kumar *et al*., 2013). According to FAOSTAT, world mushroom production was highest in China about 7.8 million tonnes in 2016. Mushroom industry in Malaysia is still low and it commercializes at a small scale. In 2014 and current, oyster mushroom (*Pleurotus* spp.*)* is mainly cultivated, accounts for 90.89% compared to other edible mushrooms produced in the world (Amin *et al*., 2014; Haimid *et al*., 2013; Rosmiza *et al*., 2016).

Volvariella volvacea is an edible mushroom derived from Plutacea family which also known as paddy straw mushroom, chinese mushroom and warm mushroom (Chang, 1977). *Volvariella volvacea* are top five most commercialized mushrooms in the world (Chang, 1977; Ahlawat *et al*., 2010; Roy *et al*., 2014). However in Malaysia, *V. volvacea* is not widely cultivated and it accounts for only 0.47% of mushroom production (Rosmiza *et al*., 2016). *Volvariella volvacea* were grown at high temperature in tropics and subtropics climate which is in the range of 30-35 ºC (Chang, 1977; Thakur and Singh, 2014). *Volvariella volvacea* became popular because it provides distinct flavor and taste where it also has shorter cropping duration (Rajapakse, 2011 and Jamjumroon *et al*., 2012). Besides that, *V. volvacea* is a good source of vitamin, bioactive compound, proteins, and amino acids until it is known as therapeutic food (Alam *et al*., 2011; Rajapakse, 2011; Guo *et al*., 2012; Sithole *et al*., 2017). Therefore, this mushroom has a very high potential for commercialization purposes as great food source to the consumers.

The commercial potential of *V. volvacea* is restricted to their very short shelf life, which is 1-2 days under ambient temperature. Thus, most of the time, this mushroom was sold directly after harvest or being processed for canning (Rai and Arumuganathan 2008). According to Ye *et al*. (2012), faster senescence of mushroom lessens the commercial value of harvested mushroom. *Volvariella volvacea* mushroom usually consumed within 6-8 hours to prevent the veil opening, maintain its freshness, quality, and texture (Thiribhuvanamala *et al*., 2012). The high respiration rate and lacking of physical protection in avoiding water loss becomes the primary factors that are often associated with quality deterioration. Therefore, postharvest study is very important in preserving and maintaining the harvested mushroom (Dhalsamant *et al*., 2015; Jamjumroon *et al*., 2012; Jaworska *et al*., 2011). Retaining quality of mushroom at first place would benefit either mushroom industry or consumers.

The time of maturity and the harvesting of *V. volvacea* remains one of the important factors enhancing the postharvest life of the mushroom. Harvest decision is done traditionally by farmer through observation and experience overlooking the nutritional quality of *V. volvacea*. Different maturity stages of mushroom may contribute to different advantage and contents. Mature stage (veil open) mushroom stays longer and absorbed more minerals from cultivation media compared to immature stage. Since mushroom absorbs nutrient from surrounding, it has become an indicator to determine heavy metal pollution (Kotwaliwale *et al*., 2007; Peng and Wang, 2013; Rajapakse, 2011; Tuzen, 2003). Assessment of safety limit intake through estimated daily intake (EDI) and target hazard quotient (THQ) could disclose the toxicity level of mushroom towards consumers (Ihugba *et al*., 2018; Huang *et al*., 2015). Cultivation medium of mushroom should be within safe limit intake through health risk assessment.

Other postharvest problems of this mushroom include browning, chilling injuries and weight loss (Rai and Arumuganathan 2008; Jamjumroon *et al*., 2012). This was due to high metabolic and respiration rate occur in mushroom. Despite that chilling injuries problem, mushrooms also deteriorated, increased its respiration rate when subjected to higher temperature which mainly due to elevation of microbial contamination and physiological activity (Valerie and David, 2008). The surrounding temperature greatly affects the metabolic activity of mushroom after harvest. According to Singh *et al*. (2010), external factor like temperature is one of the main key contributors affecting the respiration. These problems commonly can be controlled by applying suitable storage temperature along its storage duration and thus reducing the deterioration rate and postharvest loss.

Postharvest treatment and technology like packaging plays a critical role in the controlling senescence rate in mushroom by acting as important physical barrier at first line protection that powerfully controls its surrounding moisture, respiration, and metabolic activity that lead to mushroom's quality. According to Ye *et al*. (2012), packaging system under passive modified atmosphere packaging (MAP) developed gaseous components naturally resulted from the respiration and packaging permeability. MAP with proper technique was established to be a successful tool in extending mushroom shelf life (Kim *et al*., 2006; Valerie and David, 2008). Common packaging systems implemented for mushrooms including vacuum packaging (Burg and Burg 1966; Tsang 1999), perforated packaging (Dhalsamant *et al*., 2015), and film wrap (Li *et al*., 2017). Previous study implemented the microperforated type, vacuum packaging using glass jar, by sampling the mushroom without independent cultivation which could retain its shelf life 2-6 days. Current study improved by monitor its cultivation technique and using macroperforated, vacuum using plastic material. The packaging system contributed to the longer shelf life of mushroom during storage.

High perishability after harvest and time consuming during transport chain to market became a major bottleneck in the mushroom production. Storage temperature and packaging system have been demonstrated to give a greater impact in slowing down the deterioration rate, retaining physical qualities and extending shelf life of mushrooms. Therefore, the study has been conducted to improve and maintain the quality of mushroom throughout storage durations.

Proper postharvest treatment might extend the shelf life, slow down deterioration, retain physical quality and eventually reduce the postharvest losses. Therefore, the objectives of this study are

(i) to evaluate the quality, antioxidant activity, and safety limit intake of *V. volvacea* at button and veil opening stages,
(ii) to determine the postharvest qualities and antioxidant activity at different storage temperatures and durations, and
(iii) to examine the optimum packaging systems applied to *V. volvacea* at different storage durations.

REFERENCES

Aday, M. S. (2016). Application of electrolyzed water for improving postharvest quality of mushroom. *LWT- Food Science and Technology*, 68: 44-51.

Ahlawat, O. P., Gupta, P., Kamal, S. and Dhar, B. L. (2010). Variability in intra-specific and monosporous isolates of *Volvariella volvacea* based on enzyme activity, ITS and RAPD. *Indian Journal of Microbiology,* 50 (2): 192-198.

Ahlawat, O. P., Mohapatra, K. B., Kaur, H., Singh, M. (2014). Genetic variability in strains of *Volvariella volvacea* collected from the state of Odisha, India. *In: Proceedings of the 8th International Conference on Mushroom Biology and Mushroom Products* (ICMBMP8), Odisha, India: 135-144.

Ahlawat, O. P. and Tewari, R. P. (2007). Cultivation technology of paddy straw mushroom (*Volvariella volvacea*). Technical Bulletin. *National Research Centre for Mushroom (Indian Council of Agricultural Research)*. Yugantar and Prakashan Pvt. Ltd, New Delhi: 1-36.

Alam, N., Yoon, K. N., Lee, T. S. and Lee, U. Y. (2011). Hypolipidemic activities of dietary Pleurotus ostreatus in hypercholesterolemic rats. *Journal of Mycobiology,* 39(1): 45-51.

Ali, A., Chong, C. H., Mah, S. H., Abdullah, L. C., Choong, T. S. Y. and Chua, B. L. (2018). Impact of storage conditions on the stability of predominant phenolic constituents and antioxidant activity of dried Piper betle extracts. *Molecules,* 23: 1-15.

Alikhani-Koupaei, M., Mazlumzadeh, M., Sharifani, M. and Adibian, M. (2014). Enhancing stability of essential oils by microencapsulation for preservation of button mushroom during postharvest. *Journal of Food Science Nutrient*, 2: 526–533.

Alothman, M., Bhat, R. and Karim, A. A. (2009). Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. *Food Chemistry,* 115: 785-788.

Aloupi, M., Koutrotsios, G., Koulousaris, M. and Kalogeropaulos, N. (2012). Trace metal contents in wild edible mushrooms growing on serpentine and volcanic soils on the island of Lesvos, Greece. *Journal of Ecotoxicology and Environmental Safety,* 78: 184-194.

Amin, M. Z. M., Harun, A. and Wahab, M. A. M. A. (2014). Status and potential mushroom industry in Malaysia. *Economic and Technology Management Review,* 9: 103-111.

Antmann, G., Ares, G., Lema, P. and Lareo, C. (2008). Influence of modified atmosphere packaging on sensory quality of shiitake mushrooms. *Postharvest Biology and Technology,* 49 (1): 164-170.

AOAC, Association of Official Analytical Chemist, Inc. (1990). Official Methods of Analysis, 18th Ed., Wasgington DC, USA, 684pp. https://law.resource.org/pub/us/cfr/ibr/002/aoac.methods.1.1990.pdf (accessed on 24 January 2018).

Ares, G., Parentelli, C., Gambaro, A., Lareo, C. and Lema, P. (2006). Sensory shelf life of shiitake mushrooms stored under passive modified atmosphere. *Postharvest Biology and Technology,* 41: 191-197.

Arumuganathan, T., Manikantan, M. R., Indurani, C., Rai, R. D. and Kamal, S. (2010). Texture and quality parameters of oyster mushroom as influenced by drying methods. *International Agrophysics,* 24: 339-342.

Ayodele, S. M. and Okhuoya, J. A. (2009). Nutritional and phytochemical evaluation of cultivated *Psathyrella atroumbonata Pegler*, a Nigerian edible mushroom. *South African Journal of Science,* 105: 158-160.

Azevedo, S., Cunha, L. M., Oliveira, J. C., Mahajan, P. V. and Fonseca, S. C. (2017). Modelling the influence of time, temperature and relative humidity conditions on the mass loss rate of fresh oyster mushrooms. *Journal of Food Engineering,* 212: 108-112.

Bakir, T., Karadeniz, M. and Unal, S. (2018). Investigation of antioxidant activities of *Pleurotus ostreatus* stored at different temperatures. *WILEY Food Science and Nutrition*, 6: 1040-1044.

Bao, D., Gong, M., Zheng, H., Chen, M., Zhang, L., Wang, H., Jiang, J. P., Wu, L., Zhu, Y., Zhu, G., Zhou, Y., Li, C., Wang, S., Zhao, Y., Zhao, G. and Tan, Q. (2013). Sequencing and comparative analysis of the straw mushroom (*Volvariella volvacea*) genome. *PLOS ONE,* 8(3): 1-12.

Barros, L., Baptista, P. and Ferreira, I. C. F. R. (2007). Effect of *Lactarius piperatus* fruiting body maturity stage on antioxidant activity measured by several biochemical assays. *Food and Chemical Toxicology,* 45: 1731-1737.

Barros, L., Cruz, T., Baptista, T., Estevinho, L. M., and Ferreira, I. C. F. R. (2008). Wild and commercial mushrooms as source of nutrients and nutraceuticals. *Food and Chemical Toxicology,* 46: 2742-2747.

Belewu, M. A. and Belewu, K. Y. (2005). Cultivation of mushroom (*Volvariella volvacea*) on banana leaves. *African Journal of Biotechnology*, 4(12): 1401-1403.

Bernas, E., Jaworska, G., and Kmiecik, W. (2006). Storage and processing of edible mushrooms. *Acta Scientarium Polonorum Technologia Alimentaria,* 5(2): 5-23.

Bobek, P. and Galbavy, S. (1999). Hypocholesterolemic and antiatherogenic effect of oyster mushroom (*Pleurotus ostreatus*) in Rabbit. *Nahrung,* 43 (5): 339-342.

Boonsong, S., Klaypradit, W. and Wilaipun, P. (2016). Antioxidant activities of extracts from five edible mushrooms using different extractants. *Journal of Agriculture and Natural Resources,* 50: 89-97.

Brahmi, F., Mechri, B., Dhibi, M. and Hammami, M. (2015). Effect of growth stage and solvent extract on the antioxidant potential of olive leaves. *Journal of Plant Sciences,* 3(3-1): 1-7.

Breene, W. (1990). Nutritional and medicinal value of speciality mushrooms. *Journal of Food Protection,* 53: 883–894.

Burg, S. P. and Burg, E. A. (1966). Fruit storage at subatmospheric pressures. *Journal of Sciences,* 153 (3733): 314-315.

Camargo, J. M., Dunoyer, A. T. and Zapateiro, A. G. (2016). The effect of storage temperature and time on total phenolics and enzymatic activity of sapodilla (*Achras sapota L*.). *Rev.Fac.Nac.Agron,* 69(2): 7955-7963.

Chang, S. T. (1977). The origin and early development of straw mushroom cultivation. *Economic Botany,* 31: 374-376.

Chang, S. T. and Busswell, J. A. (1996). Mushroom nutriceuticals. *World Journal of Microbiology Biotechnology,* 12: 473-476.

Chang, S. T. and Quimio, T. H. (1982). *Tropical mushrooms: biological nature and cultivation methods*. Hong Kong: The Chinese University Press Hong Kong.

Chang, S. T., Busswell, J. A. (1996). Mushroom nutriceuticals. *World Journal of Microbiology Biotechnology,* 12: 473-476.

Chang, S. T. and Miles P. G. (1991). Recent trends in world production of cultivated edible mushrooms. *Journal of Mushroom,* 504: 15-18.

Chang, S. T. and Miles, P. G. (2004). *Mushrooms: cultivation, nutritional value, medicinal effect, and environmental impact*. Boca Raton, Florida, USA: CRC Press.

Chetti, M. B., Deepa, G. T., Antony, R. T., Khetagoudar, M. C., Uppar, D. S. and Navalgatti, C. M. (2012). Influence of vacuum packaging and long term storage on quality of whole chilli (*Capsicum annuum* L.). *Journal of Food Science and Technology*, 51(10): 1-6.

Cook, N. C. and Samman, S. (1996). Flavonoids- chemistry, metabolism, cardioprotective effects, and dietary sources. *Nutritional Biochemistry,* 7: 66-76.

Czapski, J. and Szudyga, K. (2000). Frozen mushrooms quality as affected by strain, flush, treatment before freezing, and time of storage. *Journal of Food Science*, 65(4): 722–725.

D'Archivio, M., Filesi, C., Vari, R., Scazzochio, B. and Masella, R. (2010). Bioavailability of polyphenols: status and controversies. *International Journal of Molecular Sciences,* 11: 1321-1342.

Dama, C. L., Kumar, S., Mishra, B. K., Shukla, K. B., Mathur, S. and Doshi, A. (2010). Antioxidative enzymatic profile of mushrooms stored at low temperature. *Journal of Food Science and Technology,* 47(6): 650-655.

Dar, B. N., Sharma, S. and Nayik, G. A. (2016). Effect of storage period on physiochemical, total phenolic content and antioxidant properties of bran enriched snacks. *Food Measure,* 10: 755-761.

Deepa, G. T., Chetti, M. B., Khetagoudar, M. C. and Adavirao, G. M. (2013). Influence of vacuum packaging on seed quality and mineral contents in chilli (*Capsicum annuum* L.). *Journal of Food Science and Technology*, 50(1): 153-158.

Dhalsamant, K., Dash, S. K., Bal, L. M. and Panda, M. K. (2015). Effect of perforation mediated MAP on shelf life of mushroom. *Scientia Horticulturae,* 189: 41-50.

Dijk, E., Hoogeveen, A. and Abeln, S. (2015). The hydrophobic temperature dependence of Amino Acids Directly calculated from protein structures. *PLOS Computational Biology*, 1-17.

Dixon, R. A. and Paiva, N. L. (1995). Stress-induced phenylpropanoid metabolism. *The Plant Cell,* 7: 1085-1097.

Dolatabadi, K. S. M., Dehghan, G., Hosseini, S., and Esfahlan, A. J. (2015). Effect of five year storage on total phenolic content and antioxidant capacity of almond (*Amygdalus communisL*.) hull and shell from different genotypes . *Avicenna Journal of Phytomedicine,* 5(1): 26-33.

Du, Y., Dou, S., and Wu, S. (2012). Efficacy of phytic acid as an inhibitor of enzymatic and non-enzymatic browning in apple juice. *Food Chemistry,* 135: 580-582.

Escriche, I., Serra, J. A., Gomez, M. and Galotto, M. J. (2001). Effect of ozone treatment and storage temperature on physicochemical properties of mushrooms (*Agaricus bisporus*). *Food Science and Technology International,* 7(3): 251-258.

FAO (Food Administration Organization), 1983. Compilation of legal limits for hazardous substances in fish and fishery products. FAO Fisheries Circular. 764. FAO, Rome, 102pp. http://www.fao.org/fi/oldsite/eims_search/1_dett.asp?calling=simple_s_result&lang=fr&pub_id=65155 (accessed on 18 January 2018)

Fasidi, I. O. (1996). Study on *Volvariella esculenta* (Mass) Singer: cultivation on agricultural wastes and proximate composition of stored mushrooms. *Food Chemistry,* 55(2): 161-163.

Ferreira, I. C. F. R., Barros, L. and Abreu, R. M. V. (2009). Antioxidants in wild mushrooms. *Current Medical Chemistry*, 16(12): 1-18.

Food and Agriculture Organization. (1972). Food Composition Table for Use in East Asia. Food Policy and Nutrition Division, U.N. Rome.

Fu, H. Y. and Shieh, D. E. (2002). Antioxidant and free radical scavenging activities of edible mushrooms. *Journal of Food Lipids,* 9: 35-46.

Galani, J. H. Y., Patel, J. S., Patel, N. J. and Talati, J. G. (2017). Storage of fruits and vegetables in refrigerator increases their phenolic acids but decreases the total phenolics, anthocyanins and vitamin c with subsequent loss of their antioxidant capacity. *Antioxidants,* 6: 1-19.

Gan, C. H., Nurul Amira, B. and Asmah, R. (2013). Antioxidant analysis of different types of edible mushrooms (*Agaricus bisporus* and *Agaricus brasiliensis*). *International Food Reasearch Journal,* 20(3): 1095-1102.

Gholami, R., Ahmadi, E. and Farris, S. (2017). Shelf life extension of white mushroom (*Agaricus bisporus*) by low temperatures conditioning, modified atmosphere, and nanocomposite packaging material. *Food Packaging and Shelf Life,* 14: 88-95.

Gorris, L. G. M. and Peppelenbos, H. W. (1992). Modified atmosphere and vacuum packaging to extend the shelf life of respiring food products. *Journal of Horticultural Technologies,* 2(3): 303-309.

Gruz, J., Ayaz, F. A., Torun, H. and Strnad, M. (2011). Phenolic acid content and radical scavenging activity of extracts from medlar (*Mespilus germanica L*.) fruit at different stages of ripening. *Food Chemistry,* 124: 271-277.

Guo, Y. J., Deng, G. F., Xu, X. R., Wu, S., Li, S., Xia, E. Q., Li, F., Chen, F., Ling, W. H. and Li, H. B. (2012). Antioxidant capacities, phenolic compounds and polysaccharide contents of 49 edible macro-fungi. *Food and Function,* 3: 1195-1205.

Haimid, M. T., Rahim, H. and Dardak, R. A. (2013). Understanding the mushroom industry and its marketing strategies for fresh produce in Malaysia. *Economic and Technology Management Review,* 8: 27-37.

Heim, K. E., Tagliaferro, A. R. and Bobilya, D. J. (2002). Flavonoid antioxidants: chemistry, metabolism and structure-activity relationships. *Journal of Nutritional Biochemistry,* 13: 572-584.

Huang, Q., Jia, Y., Wan, Y., Li, H. and Jiang, R. (2015). Market survey and risk assessment for trace metals in edible fungi and the substrate role in accumulation of heavy metals. *Journal of Food Science,* 80: 612-618.

Hung, P. V. and Nhi, N. N. Y. (2012). Nutritional composition and antioxidant capacity of several edible mushrooms grown in Southern Vietnam. *International Food Reasearch Journal,* 19(2): 611-615.

Hyde, K. D. (2003). Mycology and its future in the Asia region. *Journal of Fungal Diversity,* 13: 59-68.

Ihugba, U. A., Nwoko, C. O., Tony-Njoku, F. R., Ojiaku, A. A. and Izunobi, L. (2018). Heavy metal determination and health risk assessment of oyster mushroom *Pleurotus tuberregium* (Fr.) Singer, collected from selected markets in imo state. NIGERIA. *American Journal of Environmental Protection,* 6(1): 22-27.

Ioannou, I. and Ghoul, M. (2013). Prevention of enzymatic browning in fruit and vegetables. *European Scientific Journal,* 9(30): 310-341.

IRIS Integrated Risk Information System. (2000). Supplementary guidance for conducting health risk assessment of chemical mixtures. *US Environmental Protection Agency*. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=22567#Download (accessed on 23.01.18)

Jafri, M., Jha, A., Bunkar, D. S. and Ram, R. C. (2013). Quality retention of oyster mushrooms (*pleurotus florida*) by a combination of chemical treatments and modified atmosphere packaging. *Postharvest Biology and Technology,* 76: 112-118.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B. and Breeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology,* 7(2): 60-72.

Jamjumroon, S., Wongs-Aree, C., Srilaong, V., Kanlayanarat, S. and Chalermglin, P. (2010). Response of straw mushroom under low temperature storage. *Acta Horticulturae*, 875: 145-150.

Jamjumroon, S., Wongs-Aree, C., McGlasson, W. B., Srilaong, V., Chermklin, P. and Kanlayanarat, S. (2013). Alleviation of cap browning of 1-MCP /High CO_2- treated straw mushroom buttons under MAP. *International Food Research Journal,* 20(2): 581-585.

Jamjumroon, S., Wongs-Aree., C., McGlasson, W. B., Srilaong, V., Chalermklin, P. and Kanlayanarat, S. (2012). Extending the shelf-life of straw mushroom with high carbon dioxide treatment. *Journal of Food, Agriculture and Environment,* 10(1): 78-84.

Javan, A. J., Nikmanesh, A., Keykhosravy, K., Maftoon, S., Zare, M. A., Bayani, M., Parsaiemehr, M. and Raeisi, M. (2015). Effect of citric acid dipping treatment on bioactive components and antioxidant properties of sliced button mushroom (*Agaricus bisporus*). *Journal of Food Quality and Hazards Control,* 2: 20-25.

Jaworska, G. and Bernas, E. (2010). Effects of pre-treatment, freezing and frozen storage on the texture of *Boletus edulis* (Bull: Fr) mushrooms. *International Journal of Refrigeration*, 33: 877–855.

Jaworska, G., Bernas, E. and Mickowska, B. (2011). Effect of production process on the amino acid content of frozen and canned *Pleurotus ostreatus* mushrooms. *Food Chemistry,* 125: 936-943.

Jiang, T. (2013). Effect of alginate coating on physicochemical and sensory qualities of button mushrooms (*Agaricus bisporus*) under a high oxygen modified atmosphere. *Postharvest Biology and Technology,* 76: 91-97.

Johnsy, G. and Kaviyarasans, V. (2015). Proximate composition, minerals and amino acid composition of a two edible mushroom *Termitomycetes microcarpus* and *T. heimii*. *American Journal of Pharmacy and Health Research,* 3(1): 2321-3647.

Jolivet, S., Arpin, N., Wicher, H. J. and Pellon, G. (1998). *Agaricus bisporus* browning: A review. *Journal of Mycological Research,* 102(12): 1459–1483.

Joshi, K., Warby, J., Valverde, J., Tiwari, B., Cullen, P. J. and Frias, J. M. (2018). Impact of cold chain and product variability on quality attributes of modified atmosphere packed mushrooms (*Agaricus bisporus*) throughout distribution. *Journal of Food Engineering,* 232: 44-55.

Kalac, P. and Svoboda, L. (2000). A review of trace element concentrations in edible mushrooms. *Food Chemistry*, 69: 273-281.

Kasprzak, K. S. and Salnikow, K. (2007). Nickel toxicity and carcinogenesis. *Metal ions in life science*, 2: 619–660.

Kavanagh, K. (2011). *Fungi. Biology and Application*. Second Edition. Oxford, UK: Wiley-Blackwell.

Kayode, R. M. O., Olakulehin, T. F., Adedeji, B. S., Ahmed, O., Aliyu, T. H. and Badmos, A. H. A. (2015). Evaluation of amino acid and fatty acid profiles of commercially cultivated oyster mushroom (*Pleurotus sajor-caju*) grown on gmelina wood waste. *Nigerian Food Journal,* 33: 18-21.

Khani, R., Moudi, M. and Khojeh, V. (2017). Contamination level, distribution and health risk assessment of heavy and toxic metallic and metalloid elements in a cultivated mushroom *Pleurotus florida* (Mont.) singer. *Journal of Environmental Science and Pollution Research,* 24: 4699-4708.

Kim, D. and Seo, J. (2018). A Review: breathable films for packaging applications. *Trends in Food Science and Technology,* 76: 15-27.

Kim, K. M., Ko, J. A., Lee, J. S., Park, H. J. and Hanna, M. A. (2006). Effect of modified atmosphere packaging on the shelf-life of coated whole and sliced mushrooms. *LWT Food Science and Technology,* 39: 364-371.

Kortei, N. K., Odamtten, G. T., Appiah, V., Obodai, M., Mensah, D. L. N., Akonor, P. T., Kwagyan, M. W., Akonor, M. A. and Adaboro, R. M. (2016). preliminary shelf life studies of in-vitro antioxidant potential of gamma irradiated dried mushrooms (*Pleurotus ostreatus* Ex. Fries) Kummer in Ghana. *British Journal of Pharmaceutical Research*, 9(2): 1-13.

Kotwaliwale, N., Bakane, P. and Verma, A. (2007). Changes in textural and optical properties of oyster mushroom during hot air drying. *Journal of Food Engineering,* 78: 1207-1211.

Kozarski, M., Klaus, A., Jakovljevic, D., Todorovic, N., Vunduk, J., Petrovic, P., Niksic, M., Vrvic, M.M. and Griensven, L. V. (2015). Antioxidants of edible mushrooms. *Molecules,* 20: 19489-19525.

Kukura, J. L., Beelman, R. B., Peiffer, M. and Walsh, R. (1998). Calcium Chloride Added to Irrigation Water of Mushrooms (*Agaricus Bisporus*) Reduces Postharvest Browning. *Journal of Food Science,* 63(3): 454-457.

Kumar, A., Singh, M. and Singh, G. (2013). Effect of different pretreatments on the quality of mushrooms during solar drying. *Journal of Food Science and Technology,* 50(1): 165-170.

Kumar, S. and Pandey, A. K. (2013). Chemistry and Biological Activities of Flavonoids: An Overview. *The Scientific World Journal,* 1-16.

Kumari, A. and Baskaran, P. (2015). *An Overview on Mushroom Technology: Cultivation, Harvesting, Post-Harvest Management and Marketing.* Delhi, India: Manglam Publication.

Ladaniya, M. S. (2008). Precooling and refrigeration. in book: *Citrus fruit: biology, technology and evaluation* (pp. 319-331). Atlanta, USA: Elsevier Inc.

Lee, S. K. and Kader, A. A. (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biology and Technology,* 20: 207-220.

Li, G. S. F. and Chang, S. T. (1982). The nucleic acid content of some edible mushrooms. *European Journal of Applied Microbiology and Biotechnology,* 15: 237-240.

Li, N., Chen, F., Cui, F., Sun, W., Zhang, J., Qian, L., Yang, Y., Wu, D., Dong, Y., Jiang, J. and Yang, H. (2017). Improved postharvest quality and respiratory activity of straw mushroom (*Volvariella volvacea*) with ultrasound treatment and controlled relative humidity. *Scientia Horticulturae,* 225: 56-64.

Liang, T., Yue, W. and Li, Q. (2010). Comparison of the phenolic content and antioxidant activities of *Apocynum venetum* L. (Luo-Bu-Ma) and two of its alternative species. *International Journal of Molecular Sciences,* 11: 4452-4464.

Lopez, C. C., Alejo, E. J. S., Pompa, S. S., Rojas, R., Ruiz, J. A. and Avila, G. C. G. M. (2016). Fluctuations in phenolic content, ascorbic acid and total carotenoids and antioxidant activity of fruit beverages during storage. *Heliyon,* 2: 1-16.

Lu, J. M., Lin, P. H., Yao, Q. and Chen, C. (2010). Chemical and molecular mechanisms of antioxidants: experimental approaches and model systems. *Molecular Medicine,* 14(4): 840-860.

Ma G., Yang, W., Zhao, L., Pei, F., Fang, D. and Hu, Q. (2018). A critical review on the health promoting effects of mushrooms nutraceuticals. *Food Science and Human Wellness,* 7: 125-133.

Mahajan, P. V., Rodrigues, F. A. S., Motel, A. and Leonhard, A. (2008). Development of a moisture absorber for packaging of fresh mushrooms (*Agaricus bisporus*). *Postharvest Biology and Technology,* 48: 408-414.

Mangaraj, S., Goswami, T. K. and Mahajan, P. V. (2009). Applications of plastic films for modified atmosphere packaging of fruits and vegetables: a review. *Food Engineering Reviews,* 1: 133-158.

Manzi, P., Gambelli, L., Marconi, S., Vivanti, V. and Pizzoferrato, L. (1999). Nutrients in edible mushrooms : an inter-species comparative study. *Food Chemistry,* 65: 477-482.

Mohd, Y. S., Manas, M. A., Wagiran, M. H. and Taib, O. (2014). Penanaman cendawan jerami padi (Cultivation of paddy straw mushroom). *Buletin Teknologi MARDI*, 5, 63-69.

Miliauskas, G., Venskutonis, P. R. and Beek, T. A. V. (2004). Screening of radical scavenging activity of some medicinal and aromatic plant extracts. *Food Chemistry,* 85: 231-237.

Mohapatra, D., Frias, J. M., Oliveira, F. A. R., Bira, Z. M. and Kerry, J. (2008). Development and validation of a model to predict enzymatic activity during storage of cultivated mushrooms (*Agaricus bisporus spp*.) *Journal of Food Engineering,* 86: 39-48.

Moon, B. and Lo, Y. M. (2014). Conventional and novel applications of edible mushrooms in today's food industry. *Journal of Food Processing and Preservation*, 38: 2146–2153.

Mujumdar, A. S. and Law, C. L. (2010). Drying technology: Trends and applications in postharvest processing. *Food Bioprocess Technology*, 3: 853–852.

Nur Sakinah, M. J., Misran, A., Mahmud, T. M. M. and Abdullah, S. (2019). A review: Production and postharvest management of *Volvariella volvacea*. *International Food Research Journal*, 26(2): 367-376.

Orisakwe, O. E., Nduka, J. K., Amadi, C. N., Dike, D. O. and Bede, O. (2012). Heavy metals health risk assessment for population via consumption of food crops and fruits in Owerri, South Eastern, Nigeria. *Chemistry Central Journal*, 6: 1-7.

Ouzouni, P. K., Petridis, D., Koller, W. D. and Riganakos, K. A. (2009). Nutritional value and metal content of wild edible mushrooms collected from West Macedonia and Epirus, Greece. *Food Chemistry*, 115: 1575-1580.

Pathak, V. N., Nagendra, Y. and Maneesha, G. (1998). *Mushroom Production and Processing Technology*. Bikaner, India: Agro botanical publisher.

Pehlivan, E., Altun, T., Cetin, S. and Bhanger, M. I. (2009). Lead sorption by waste biomass of hazelnut and almond shell. *Journal of Hazardous Materials,* 167: 1203-1208.

Peng, E. C. and Wang, J. J. (2013). A study of production of radioactive environmental reference materials used for proficiency testing program in Taiwan. *Applied Radiation and Isotopes,* 81: 14-20.

Punitha, S. C. and Rajasekaran, M. (2014). Free radical scavenging activity of fruiting body extracts of an edible mushrooms, *Volvariella volvacea* (Bull. Ex Fr.) Singer: an in vitro study. *Asian Journal of Biomedical and Pharmaceutical Sciences,* 4(30): 6-11.

Queiroz, C., Lopes, M. L. M., Fialho, E. and Mesquita, V. L. V. (2011). Changes in bioactive compounds and antioxidant capacity of fresh-cut cashew apple. *Food Research International*, 44: 1459-1462.

Queiroz, C., Lopes, M. L. M., Fialho, E. and Valente-Mesquita, V. L. (2008). Polyphenol Oxidase: characteristics and mechanisms of browning control. *Food Reviews International,* 24(4): 361-375.

Rai, R. D. and Arumuganathan, T. (2008). *Post harvest technology of mushrooms.* India: National Research Centre for Mushroom (Indian Council of Agricultural Research).

Rajapakse, P. (2011). New cultivation technology for paddy straw mushroom (*Volvariella volvacea*). *International Conference on Mushroom Biology and Mushroom Products.* Arcachon, France: World Society of Mushroom Biology and Mushroom Products.

Ramos, I. R. and Andrade, C. D. (2017). The beneficial role of edible mushrooms in human health. *Current Opinion in Food Science,* 14: 122-128.

Razak, N. A., Hamid, N. A. and Shaari, A. R. (2018). Effect of vacuum and non-vacuum packaging on total phenolic content of encapsulated *Orthosiphon stamineus* spray-dried powder during storage. *Solid State Phenomena*, 280: 330-334.

Rosmiza, M. Z., Davies, W. P., Rosniza Aznie, C. R., Jabil, M. J. and Mazdi, M. (2016). Prospects for increasing commercial mushroom production in malaysia: challenges and opportunities. *Mediterranean Journal of Social Sciences,* 7: 406-415.

Roy, A., Prasad, P. and Gupta, N. (2014). *Volvariella volvacea*: A macrofungus having nutritional and health potential. *Asian Journal of Pharmaceutical Technology,* 4(2): 110-113.

Roy, A. and Prasad, P. (2016). Determination of physicochemical, phytochemical and antioxidant activity of *Volvariella volvacea*. *American Journal of Pharmtech Research,* 6(2): 642-654.

Rux, G., Mahajan, P. V., Geyer, M., Linke, M., Pant, A., Saengerlaub, S. and Caleb, O. J. (2015). Application of humidity-regulating tray for packaging of mushrooms. *Postharvest Biology and Technology,* 108: 102-110.

Saha, A. K., Acharya, S. and Roy, A. (2012). Antioxidant level ofwild edible mushroom: *Pleurotus djamor* (Fr.) Boedijn. *Journal of Agricultural Technology*, 8(4): 1343-1351.

Saltveit, M. E. (2000). Wound induced changes in phenolic metabolism and tissue browning are altered by heat shock. *Postharvest Biology and Technology,* 21: 61-69.

Sams, C. E. (1999). Postharvest factors affecting postharvest texture. *Postharvest Biology and Technology,* 15: 249-254.

Sanchez, C. L. D. T., Lomeli, M. G., Cervantes, E. L., Zurita, F., Garcia, M. A. R., Cruz, S. R., Aguilar, J. A., Rio, J. A. M. D. and Medina, P. J. G. (2015). Storage effect on phenols and on the antioxidant activity of extracts from *Anemopsis californica* and inhibition of elastase enzyme. *Journal of Chemistry,* 1-9.

Siah, W. M., Faridah, H., Rahimah, M. Z., Tahir, S. M. and Zain, D. M. (2011). Effects of packaging materials and storage on total phenolic content and antioxidant activity of *Centella asiatica* drinks. *Journal of Tropical Agriculture and Food Science,* 39(1): 1-7.

Singh, P., Langowski, H-C., Wani, A. A. and Saengerlaub, S. (2010). Recent advances in extending the shelf life of fresh agaricus mushrooms: a review. *Journal of Science Food Agriculture,* 90: 1393-1402.

Singh, S., Gaikwad, K. K., Lee, M. and Lee, Y. S. (2018). Thermally buffered corrugated packaging for preserving the postharvest freshness of mushrooms (*Agaricus bisporus*). *Journal of Food Engineering,* 216: 11-19.

Sithole, S. C., Mugivhisa, L. L., Amoo, S. O. and Olowoyo, J. O. (2017). Patterns and concentrations of trace metals in mushrooms harvested from trace metal-polluted soils in Pretoria, South Africa. *South African Journal of Botany,* 108: 315-320.

Soares, A. A., Souza, C. G. M., Daniel, F. M., Ferrari, G. P., Costa, S. M. G. and Peralta, R. M. (2009). Antioxidant activity and total phenolic content of *Agaricus brasiliensis* (*Agaricus blazei Murril*) in two stages of maturity. *Food Chemistry,* 112: 775-781.

Soylak, M., Saracoglu, S., Tuzen, M. and Mendil, D. (2005). Determination of trace metals in mushroom samples from Kayseri, Turkey. *Food Chemistry*, 92: 649-652.

Sun, L., Chang, W., Bao, C. and Zhuang, Y. (2017). Metal contents, bioaccumulation, and health risk assessment in wild edible Boletacea mushrooms. *Journal of Food Science,* 82(6): 1500-1507.

Taghizadeh, M., Gowen, A., Ward, P. and O'Donnell, C. P. (2010). Use of hypersppectral imaging for evaluation of shelf-life of fresh white button mushrooms (*Agaricus bisporus*) stored in different packaging films. *Innovative Food Science and Emerging Technologies,* 11: 423-431.

Tangahu, B. V., Sheikh Abdullah, S. R., Basri, H., Idris, M., Anuar, N. and Mukhlisin, M. (2011). Review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. *International Journal of Chemical Engineering,* 1-30.

Tao, F., Zhang, M., Hangqing, Y. and Jincai, S. (2006). Effect of different storage conditions on physical and chemical properties of white mushrooms after vacuum cooling. *Journal of Food Engineering,* 77: 545-549.

Thakur, M. P. and Singh, H. K. (2014). Advances in the cultivation technology of tropical mushrooms in India. *JNKVV Research Journal,* 48(2): 120-135.

Thapa, C. D., Prakasam, V. and Singh, M. (2016). Mushroom culture. 1-92Pp. Retrieved at: Agrimoon.com. Doi: https://k8449r.weebly.com/uploads/3/0/7/3/30731055/mashroom-culture-signed.pdf

Thiribhuvanamala, G., Krishnamoorthy, S., Manoranjitham, K., Praksasm, V. and Krishnan, S. (2012). Improved techniques to enhance the yield of paddy straw mushroom (*Volvariella volvacea*) for commercial cultivation. *African Journal of Biotechnology,* 64: 12740-12748.

Tlili, N., Mejri, H., Yahia, Y., Saadaoui, E., Rejeb, S., Khaldi, A. and Nasri, N. (2014). Phytochemicals and antioxidant activities of *Rhus tripartitum* (Ucria) fruits depending on locality and different stages of maturity. *Food Chemistry,* 160: 98-103.

Tripathy, S. S., Rajoriya, A., Mahapatra, A. and Gupta, N. (2016). Biochemical and antioxidant properties of wild edible mushrooms used for food by tribal of eastern India. *International Journal of Pharmacy and Pharmaceutical Sciences,* 8(4): 194-199.

Tsang, S. (1999). *Enzymatic browning of straw mushroom*, *Volvariella volvacea*. Master Thesis, The Chinese University of Hong Kong.

Tuzen, M. (2003). Determination of heavy metals in soil, mushroom and plant samples by atomic absorption spectrometry. *Microchemical Journal,* 74: 289-297.

Ukoima, H. N., Ogbonnaya, L. O., Arikpo, G. E. and Ikpe, F. N. (2009). Cultivation of mushroom (*Volvariella volvacea*) on various farm wastes in Obubra local government of cross river state, Nigeria. *Pakistan Journal of Nutrition,* 8(7): 1059-1061.

Ul Haq, I., Khan, M. A., Khan, S. A. and Ahmad, M. (2011). Biochemical analysis of fruiting bodies of *Volvariella volvacea* strain Vv pk, grown on six different substrates. *Journal of Soil Environment,* 30(2): 146-150.

USEPA. US Environmental Protection Agency, 2000 USEPA. US Environmental Protection Agency Guidance for assessing chemical contaminant data for use in fish advisories Vol. 1: Fish Sampling and Analysis (third ed.), U.S. Environmental Protection Agency, Washington, DC (2000) EPA-823-B-00-007. Available online at: https://www.epa.gov/sites/production/files/2015-06/documents/volume1.pdf (Accessed on 24 January 2018)

USEPA. US Environmental Protection Agency, 2015 USEPA. US Environmental Protection Agency Human health risk assessment. Regional screening level (RSL) — summary table (2015). Available online at: https://semspub.epa.gov/work/03/2218760.pdf (Accessed on 24 January 2018)

Valerie, C. B. and David, O. B. (2008). Effects of washing treatment on microbial and sensory quality of modified atmosphere (MA) packaged fresh sliced mushroom (*Agaricus bisporus*). *Postharvest Biology and Technology,* 48: 283-294.

Villaescusa, R. and Gil, M. I. (2003). Quality improvement of *Pleurotus* mushrooms by modified atmosphere packaging and moisture absorbers. *Postharvest Biology and Technology,* 28: 169-179.

Vitti, M. C. D., Sasaki, F. F., Miguel, P., Kluge, R.A. and Moretti, C. L. (2011). Activity of enzymes associated with the enzymatic browning of minimally processed potatoes. *Brazillian Archives of Biology and Technology,* 54: 983-990.

Wang, H. J., An, D. S., Rhim, J. W. and Lee, D. S. (2017). Shiitake mushroom packages turned in active CO_2 and moisture absorption requirements. *Food Packaging and Shelf Life,* 11: 10-15.

Wei, W., Lv, P., Xia, Q., Tan, F., Sun, F., Yu, W., Jia, L. and Cheng, J. (2017). Fresh-keeping effects of three types of modified atmosphere packaging of pine-mushrooms. *Postharvest Biology and Technology,* 132: 62-70.

WHO (World Health Organization). (1989). Heavy metals environmental aspects. Environment Health Criteria No. 85, Geneva, 1989. Available online at: http://www.who.int/ipcs/publications/ehc/ehc_numerical/en/ (accessed on 24 January 2018)

Woldegiorgis, A. Z., Abate, D., Haki, G. D. and Ziegler, G. R. (2014). Antioxidant property of edible mushrooms collected from Ethiopia. *Food Chemistry,* 157: 30-36.

Xiong, D., Wang, H., Chen, M., Xue, C., Li, Z., Bian, Y. and Bao, D. (2014). Application of mating type genes in molecular marker-assisted breeding of the edible straw mushroom *Volvariella volvacea*. *Scientia Horticulturae,* 180: 59-62.

Xu, B. J. and Chang, S. K. C. (2007). A comparative study on phenolic profiles and antioxidant activities of legumes as affected by extraction solvents. *Journal of Sensory and Nutritive Qualities of Food,* 72(2): 159-166.

Yang, J. H., Lin, H. C. and Mau, J. L. (2002). Antioxidant properties of several commercial mushrooms. *Food Chemistry,* 77: 229-235.

Ye, J. J., Li, J. R., Han, X. X., Zhang, L., Jiang, T. J. and Xia, M. (2012). Effects of active modified atmosphere packaging on postharvest quality of shiitake mushrooms (*Lentinula edodes*) stored at cold storage. *Journal of Integrative Agriculture,* 11(3): 474-482.

Zakhary, J. W., Rafik El-Mahdy, A., Abo-Bakr, T. M. and El Tabey-Shehata, A. M. (1984). Cultivation and chemical composition of the paddy straw mushroom (*Volvariella volvacea*). *Food Chemistry,* 13: 265-276.

Zied, D. C., Pardo, J. E., Tomaz, R. S., Miasaki, T. C. and Gimenez, A. P. (2017). Mycochemical characterization of *Agaricus subrufescens* considering their morphological and physiological stage of maturity on the traceability process. *Biomed Research International*, 1-10.

Zivanovic, S., Buescher, R. and Kim, S. K. (2003). Mushroom texture, cell wall composition, color, and ultrastructure as affected by pH and temperature. *Journal of Food Sciences,* 68(5): 1860-1865.

Zivanovic, S., Buescher, R. W. and Kim, K. S. (2000). Textural changes in mushrooms (*Agaricus bisporus*) associated with tissue ultrastructure and composition. *Journal of Sensory and Nutritive Qualities of Food,* 65(8): 1404-1408.

BIODATA OF STUDENT

The student, Nur Sakinah Mohd Joha, daughter to Mohd Joha Che Lop and Juriyah Ismail, was born on 2nd November 1992. She obtained her Malaysian Education Certificate at SMK Sultan Idris Shah II, Gerik, Perak, in 2009. She managed to complete pre university study in Perak Matriculation College in 2010. In 2015, she graduated with a degree in Bachelor of Science (Hons) Major (Biology) from Universiti Putra Malaysia.

LIST OF PUBLICATIONS

Nur Sakinah, M. J., Misran, A., Mahmud, T. M. M., Abdullah, S., and Fatin Nabilah, F. (2017). Texture and Ultrastructure of Straw Mushroom (*Volvariella Volvacea*) at Different Maturity Stages Grown on EFB Compost. Oral presentation, *ISSAAS 2017 International Congress and General Meeting. "Green Agriculture in Southeast Asia: Theories and Practices", 14th – 16th October, Vietnam National University of Agriculture, Hanoi, Vietnam.*

Fatin Nabilah Fisol, Sumaiyah Abdullah, Mahmud T.M. Mohamed, Azizah Misran, **Nur Sakinah Mohd Joha**, Azhar Mohamad, and Mohamad Yuzaidi Azmi. (2017). Effects of different empty fruit bunch (EFB) composting periods on the production of *Volvariella volvacea*. Oral presentation, *ISSAAS 2017 International Congress and General Meeting. "Green Agriculture in Southeast Asia: Theories and Practices", 14th – 16th October, Vietnam National University of Agriculture, Hanoi, Vietnam.*

Nur Sakinah Mohd Joha, Azizah Misran, Mahmud Tengku Muda Mohamed dan Sumaiyah Abdullah. (2018). Kesan pengaruh suhu dan tempoh simpanan terhadap kualiti fizikal pasca tuai *Volvariella Volvacea*. Poster presentation, *Seminar Industri Cendawan: Ladang ke kilang", 24th Mac, Malaysian Nuclear Agency, Bangi, Malaysia.*

Nur Sakinah Mohd Joha, Azizah Misran, Mahmud Tengku Muda Mohamed, Sumaiyah Abdullah and Azhar Mohamad. (2018). Maturity stages, effect of storage temperatures and durations on physical quality and ultrastructure of postharvest shelf life of straw mushroom (*Volvariella volvacea*). Poster presentation, *27th Scientific Conference of The Microscopy Society Malaysia (27th SCMSM 2018), Melaka*.

Nur Sakinah, M. J., Misran, A., Mahmud, T. M. M., Abdullah, S. (2019). A review: Production and postharvest management of *Volvariella volvacea*. *International Food Research Journal*, 26(2): 367-376.

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