Sains Malaysiana 45(11)(2016): 1617–1623

Quality Characteristics of *Pleurotus sajor-caju* Powder: Study on Nutritional Compositions, Functional Properties and Storage Stability

(Ciri Kualiti Serbuk *Pleurotus sajor-caju*: Kajian terhadap Komposisi Zat Pemakanan, Sifat Berfungsi dan Kestabilan Penyimpanan)

NG SZE HAN, WAN AMIR NIZAM WAN AHMAD & WAN ROSLI WAN ISHAK*

ASTRACT

Pleurotus sajor-caju *(PSC) is an oyster mushroom widely consumed in Asian countries and successfully cultivated in Malaysia. This study aimed to determine nutritional compositions, functional properties and storage stability of PSC powder based on storage temperature. Fresh PSC was dried using low heat air blow technique and ground into fine powder. Nutritional analyses of PSC powder were conducted following AOAC methods. Functional properties were also determined accordingly. For storage stability study, four portions of PSC powder were stored at temperature of -20, 4, 25 and 35°C separately, and then studied parameters were investigated at time 0, 3 and 6 months. PSC powder contains appreciable amounts of protein (22.41%), ash (7.79%), dietary fibre (56.99%) and β-glucan (3.32%) but low content in sucrose (0.19%) and fat (2.30%). It also possesses notable functional properties such as water holding capacity, oil holding capacity, swelling capacity and emulsifying activity. Storage stability study showed that PSC powder exhibited lower moisture content and L* colorimetric value. Meanwhile higher water activity level with increasing storage temperature but no significant difference in pH value and microbial counts were detected. Besides, storage temperature at -20, 25 and 35°C jeopardized the original colour properties of PSC powder. The best storage temperature for PSC powder is 4°C. PSC powder has the potential to be a safe and as an alternative dietary fibre rich ingredient in food industry due to its nutritional, functional and storage stability properties.*

Keywords: Dietary fibre; functional properties; nutritional compositions; Pleurotus sajor-caju *(PSC); storage stability*

ABSTRAK

Pleurotus sajor-caju *(PSC) adalah sejenis cendawan tiram yang digunakan di negara Asia secara meluas dan ditanam dengan jayanya di Malaysia. Kajian ini bertujuan untuk menentukan komposisi zat makanan, sifat berfungsi dan kestabilan penyimpanan serbuk PSC berdasarkan suhu penyimpanan. PSC segar dikeringkan dengan menggunakan teknik semburan udara haba rendah dan dikisar sehingga menjadi serbuk halus. Analisis pemakanan serbuk PSC telah dijalankan mengikut kaedah AOAC. Sifat berfungsi juga turut ditentukan. Untuk kajian kestabilan penyimpanan, empat bahagian serbuk PSC telah disimpan pada suhu -20, 4, 25 dan 35°C secara berasingan, dan kemudian parameter tertentu telah dikaji dalam masa 0, 3 dan 6 bulan. Serbuk PSC mengandungi kuantiti protein (22.41%), abu (7.79%), serat makanan (56.99%) dan β-glukan (3.32%) yang tinggi tetapi kandungan sukrosa (0.19%) dan lemak (2.30%) yang rendah. Ia juga mempunyai sifat berfungsi yang ketara seperti muatan simpanan air, muatan simpanan minyak, pembengkakan dan aktiviti mengemulsi. Kajian kestabilan penyimpanan menunjukkan serbuk PSC mempunyai kandungan lembapan dan nilai L* yang lebih rendah. Sementara itu, aktiviti air yang lebih tinggi dengan peningkatan suhu penyimpanan tetapi tiada perbezaan yang ketara pada nilai pH dan kandungan mikrob telah dikesan. Selain itu, suhu penyimpanan pada -20, 25 dan 35°C menjejaskan sifat warna asal serbuk PSC. Suhu penyimpanan yang terbaik untuk serbuk PSC adalah 4°C. Serbuk PSC berpotensi sebagai diet selamat dan alternatif ramuan diet tinggi serat dalam industri makanan disebabkan sifat pemakanan, sifat berfungsi serta sitfat kestabilan penyimpanannya.*

Kata kunci: Kestabilan penyimpanan; komposisi zat makanan; Pleurotus sajor-caju *(PSC); serat makanan; sifat berfungsi*

INTRODUCTION

In the recent decades, there is a rising demand for foods high in dietary fibre (DF) which has brought to the growth of a large market for fibre-rich ingredients and products. Since 1970s, the important aspect of dietary fibre in nutrition and health has encouraged a wide range of research activities and has become a global public health concern. Accumulating evidences from previous studies supported the perspective that increased dietary fibre intake can have favourable outcomes against several chronic diseases such as diabetes, cardiovascular diseases, some forms of cancer especially colon cancer and constipation (Bosaeus 2004; Kaczmarczyk et al. 2012). Hence, DF is collectively acknowledged to be among one of the key components in a health-promoting diet.

Discovering novel sources of DF as functional ingredients is of great interest in the food industry. Cereals and oats are the most widespread utilised sources of DF in food products. Nevertheless, DF sources derived from fruits and vegetables have been gradually innovated in the world markets due to their better nutritional quality (Chau & Huang 2003). Dietary fibres obtained from different sources might vary in their physicochemical properties, which subsequently affect their uses as ingredients in food applications and their physiological responses (Guillon & Champ 2000).

Pleurotus sajor-caju (PSC) is an excellent edible oyster mushroom featured by a white spore print, gills attachment and usually observed with an eccentric stip (Miles & Chang 1997). It is cultivated on decayed organic materials and is gaining popularity in Asian countries. It is cultivated successfully in Malaysia because of its high relative humidity and climatic condition which are suitable for the growth of this mushroom. Mushroom cultivation is a profitable agribusiness due to its cheap and simple cultivation method as well as it requires only a shorter growth time (Patrabansh & Madan 1997). This mushroom received great interest because it contains large number of biologically active compounds such as polysaccharides, pleuran and proteoglycans (Wasser 2002). Pleuran from *Pleurotus* spp. has shown marked immunity-stimulating effect and blood cholesterol-reducing effect whereas proteoglycans possess immune-modulatory and antitumor activities (Agrawal et al. 2010; Shah et al. 2007). However, polysaccharides especially dietary fibres are the most important active compounds among others. Hence, several medicinal and pharmacological properties of PSC are believed to be associated with dietary fibre which can provide functional properties (Abdul-Hamid & Luan 2000; Elleuch et al. 2011). By recognising the functional properties of PSC, one can broaden its use in the food industry and aid in formulating high quality and well-accepted food products.

Nevertheless, fresh PSC with moisture content of up to 80% is a highly perishable commodity featuring a short shelf life (Gormley 1975). It is attributed to the appearance of post-harvest changes including surface discoloration, stipe elongation, cap expansion and microbial decay (Czapski & Szudyga 2000). For this reason, the dehydration process is a widely used method to develop PSC powder for further exploitation (Wan Rosli et al. 2012). Nevertheless, storage condition may influence the physicochemical and microbiological characteristics of PSC powder, and thus affecting its quality and safety properties. Hence, optimum storage condition of PSC powder needs to be studied in order to ensure longer shelf life as well as maintain its useful physicochemical properties.

This study is aimed to investigate the nutritional compositions and functional properties of the obtained PSC powder as well as its storage stability based on storage temperature.

MATERIALS AND METHODS

SAMPLE PREPARATION

Fresh fruiting bodies of PSC (5 kg) were obtained from National Kenaf and Tobacco Board (NKTB), Malaysia. After the drying process using a low heat air blow (Bio-dehydration*) by Anjaad™, the dehydrated PSC (yield: 10% w/w) were milled and sifted into fine powder having diameter of 125 μm. The obtained PSC powder was packed in polyethylene bags and heat-sealed until further use.

NUTRITIONAL ANALYSES
PROXIMATE, SUCROSE AND CALORIFIC VALUE ANALYSES

Proximate composition analyses were conducted using methods in accordance to the AOAC (1996) for moisture, ash, protein, fat carbohydrate as well as sucrose (HPLC-ELSD method). The calorific value (cal/g) of samples was determined using a bomb calorimetry (IKA® C2000 Basic).

DF COMPOSITIONS AND B-GLUCAN ANALYSES

Insoluble DF (IDF) and soluble DF (SDF) contents of PSC powder were analysed by using an enzymatic gravimetric method, according to the AOAC 991.42, 993.19 and AACC 32-21 (AOAC 1990). Total DF (TDF) content was calculated as sum of IDF and SDF.

Determination of β-glucan was done by using the enzymatic kits which were the Mixed-Linkage Beta glucan (Megazyme, Ireland) following the AOAC Method 995.16, AACC Method 32-23.01 and ICC Standard Method No. 166 (McCleary & Glennie-Holmes 1985) with minor modification.

FUNCTIONAL PROPERTIES

Water holding capacity (WHC) and oil holding capacity (OHC) of PSC powder were determined according to the procedures outlined by Lin et al. (1974) and Robertson et al. (2000), respectively, with some modifications. The swelling capacity (SWC) was investigated following the method described by Robertson et al. (2000) with slight modifications. Emulsifying activity (EA) and emulsion stability (ES) were determined according to Chau et al. (1997) with slight modifications.

STORAGE STABILITY

STUDY DESIGN

Data were obtained with a 4 × 3 full factorial experimental design. The factors compose of 4 levels (-20, 4, 25 and 35°C) of storage temperature and 3 levels (0, 3 and 6 months) of storage duration. Samples were stored at respective temperature separately. Then, triplicate samples at each storage temperature were analysed for studied parameters at time intervals of 0, 3 and 6 months of the study.

PHYSICOCHEMICAL PROPERTIES

The water activity (A_w) of samples was analysed at 25°C by using a water activity meter (AquaLab, Washington).

Five grams of each sample were blended with 20 mL of deionized water for 2 min. The pH of the resulted suspension was measured using a pH meter (Mettler Toledo S20).

Colorimetric measurements of samples (approximately 10 g) were performed by using a Colorimeter (Minolta Model 3500, Minolta Camera Co., Ltd., Osaka, Japan). The instrument was calibrated by using a white calibration plate (CM-A124) and zero calibration box (CM-A124). The studied CIELAB coordinates were lightness (L*), red/green (a*) and yellow/blue (b*). Each sample was measured in triplicate with 5 replicate measurements.

MICROBIAL CONTENTS ANALYSES

Determination of Total Plate Count (TPC) was conducted following the method described by Pinero et al. (2008). Ten grams of sample and 90 mL of sterilized maximum recovery diluents (BDH, UK) were placed into a sterile stomacher bag (Inter Science, France). By using a stomacher (Inter Science, France), the sample was homogenized for 2 min. The homogenized sample (1 mL) was then pipetted into a sterilized 15 mL centrifuge tube (Falcon, USA) which has already been filled with 9 mL of maximum recovery diluents. A 10 fold serial dilution was carried out with dilution factor ranging from 10^1 to 10^4. One mL of each dilution was pipetted on total plate count petry film (3M Petry Film, USA) which was then incubated at 35°C for 24 to 48 h. After incubation, the petry film containing 25-250 of colonies was considered for enumeration. The colony numbers were expressed as colony forming unit (CFU) per mL.

Yeast and Mould Count (YMC) were determined under the same procedures as TPC except using Rose Bengal agar with chloramphenicol as a medium and incubated at 22-25°C for 5 days. The analysis was carried out in triplicate.

$$N = \frac{\sum C}{\left[(1 \times n_1) + (0.1 \times n_2) \times (d)\right]},$$

where N is the number of colonies per ml or g of sample; $\sum C$ is the sum of all colonies on all plates counted; n_1 is the number of plates in first dilution counted; n_2 is the number of plates in second dilution counted; and d is the dilution from which the first counts were obtained.

STATISTICAL ANALYSIS

Data obtained from storage stability study were subjected to two-way repeated measure analysis of variance (ANOVA) using the Graph Pad Prism 6.0 version software. The results were expressed as mean ± standard deviation. All experiments were replicated twice and all the measurements were carried out in triplicate (n=3). Significant level was fixed at $p<0.05$.

RESULTS AND DISCUSSION

NUTRITIONAL COMPOSITIONS

The nutritional compositions of PSC powder are presented in Table 1. Proximate analyses indicated that PSC powder contains low level of fat (2.30%) and moisture (7.04%) but high amount in protein (22.41%), ash (7.79%) and carbohydrate (60.47%), resulting in 451.60 cal/g calorific value. PSC powder possesses negligible amount of sucrose at level of 0.19% which is widely acceptable for population especially diabetic individuals who concern their blood glucose level and health status. Interestingly, appreciable amounts of TDF (56.99%), IDF (48.79%), SDF (8.21%) and β-glucan (3.32%) of PSC were also detected in PSC powder as DF is abundant in cell wall of mushroom fruiting body. High DF PSC powder can be used as an excellent food ingredient replacing refined powder or other traditional DF sources in making DF-rich health products.

TABLE 1. Nutritional compositions of PSC powder (mean ± SD)

Nutrients*	Concentration (%)
Fat	2.30 ± 0.02
Moisture	7.04 ± 0.02
Protein	22.41 ± 0.65
Ash	7.79 ± 0.41
Carbohydrate	60.47 ± 0.51
Calorific value (cal/g)	451.60 ± 2.70
Sucrose	0.19 ± 0.00
Total DF	56.99 ± 0.92
Soluble DF	8.21 ± 0.41
Insoluble DF	48.79 ± 0.90
β-glucan	3.32 ± 0.13

*The analyses were replicated thrice (n=3)

Functional properties of PSC powder (Table 2) are linked to the physical and chemical structure of plant polysaccharides. Water holding capacity (WHC) is the amount of water that remains bound to the hydrated fibre after applying an external centrifugal gravity force or compression (Raghavendra et al. 2006). PSC powder exhibited a WHC of 13.46 times of its own weight. It possessed a WHC similar to the results reported by López-Vargas et al. (2013) for passion fruit albedo. High WHC indicated that PSC powder has potential applications in food products requiring freshness preservation and viscosity development. It is because dietary fibre particle of PSC powder has the capacity to hold water by adsorption inside the fibre matrix to prevent structure deterioration. High content of TDF and SDF in PSC powder may account

TABLE 2. Functional propeties of PSC powder (mean ± SD)

Functional properties*	Values
Water holding capacity (g/g)	13.46 ± 0.28
Oil holding capacity (mL/g)	8.52 ± 0.13
Swelling capacity (mL/g)	19.49 ± 0.24
Emulsifying ability (%)	51.67 ± 0.25
Emulsion stability (%)	95.37 ± 0.21

*The analyses were replicated thrice (n=3)

for its high WHC (Grigelmo-Miguel & Martín-Belloso 1999; Lan et al. 2012). Swelling capacity (SWC) is the ability of DF to increase the bulk after absorbing water and measured as settled bed volume (Guillon & Champ 2000). It was reported that 19.49 mL/g was observed for the swelling capacity value in PSC powder. Overall, hydration properties are important properties of dietary fibre from the technological and physiological perspectives particularly its reduced glucose response ability and improved colonic function (Guillon & Champ 2000).

Oil-holding capacity (OHC) is also a technological property associated with the chemical structure of the plant polysaccharides and depends on thickness, surface properties, overall charge density and hydrophobic nature of the fibre particle (Viuda-Martos et al. 2012). In this study, PSC powder demonstrated values of 8.52 mL/g OHC which is higher (p<0.05) OHC than the other DF sources (Lario et al. 2004; Viuda-Martos et al. 2012). The ability of PSC DF to retain oil is essential in the food industry such as preventing oil losses during cooking. From the

TABLE 3. Effect of storage temperature and duration on physicochemical properties of PSC powder (mean ± SD)

Parameters		Storage temperature (°C)	Physicochemical properties storage duration (months)		
		0	3	6	
Moisture (%)		-20	7.04 ± 0.02	^{p}7.12 ± 0.02	^{pq}7.19 ± 0.01
		4	7.04 ± 0.02	7.08 ± 0.02^{a}	^{p}7.11 ± 0.01^{a}
		25	7.04 ± 0.02	7.04 ± 0.01^{ab}	^{pq}7.07 ± 0.02^{ab}
		35	7.04 ± 0.02	7.01 ± 0.01^{abc}	^{pq}6.94 ± 0.02^{abc}
Water activity (A_w)		-20	0.42 ± 0.01	0.42 ± 0.01	0.42 ± 0.01
		4	0.42 ± 0.01	0.42 ± 0.01	0.43 ± 0.01
		25	0.42 ± 0.01	0.44 ± 0.01	^{p}0.45 ± 0.01^{a}
		35	0.42 ± 0.01	0.44 ± 0.01	^{pq}0.47 ± 0.01^{ab}
Colour coordinates	L*	-20	73.37 ± 0.01	^{p}74.48 ± 0.00	^{pq}75.86 ± 0.01
		4	73.37 ± 0.01	^{p}73 67 ± 0.00^{a}	^{pq}74.58 ± 0.01^{a}
		25	73.37 ± 0.01	73.35 ± 0.01^{ab}	^{p}73.38 ± 0.01^{ab}
		35	73.37 ± 0.01	^{p}71.82 ± 0.01^{abc}	^{pq}69.93 ± 0.01^{abc}
	a*	-20	3.80 ± 0.00	^{p}2.85 ± 0.01	^{pq}2.70 ± 0.00
		4	3.80 ± 0.00	^{p}3.10 ± 0.01^{a}	^{pq}2.90 ± 0.00^{a}
		25	3.80 ± 0.00	3.81 ± 0.01^{ab}	3.80 ± 0.01^{ab}
		35	3.80 ± 0.00	^{p}4.44 ± 0.01^{abc}	^{pq}4.87 ± 0.01^{abc}
	b*	-20	24.77 ± 0.01	^{p}23.50 ± 0.00	^{pq}22.04 ± 0.01
		4	24.77 ± 0.01	^{p}23.91 ± 0.01^{a}	^{pq}22.51 ± 0.01^{a}
		25	24.77 ± 0.01	^{p}24.75 ± 0.01^{ab}	24.76 ± 0.01^{ab}
		35	24.77 ± 0.01	^{p}25.38 ± 0.01^{abc}	^{pq}26.35 ± 0.01^{abc}
	C	-20	25.06 ± 0.01	^{p}23.67 ± 0.01	^{pq}22.09 ± 0.01
		4	25.06 ± 0.01	^{p}24.11 ± 0.00^{a}	^{pq}23.14 ± 0.01^{a}
		25	25.06 ± 0.01	25.05 ± 0.01^{ab}	^{p}25.04 ± 0.01^{ab}
		35	25.06 ± 0.01	^{p}25.94 ± 0.01^{abc}	^{pq}26.52 ± 0.01^{abc}
	H	-20	81.27 ± 0.01	^{p}83.11 ± 0.00	^{pq}84.27 ± 0.01
		4	81.27 ± 0.01	^{p}82.62 ± 0.01^{a}	^{pq}83.68 ± 0.01^{a}
		25	81.27 ± 0.01	81.26 ± 0.00^{ab}	^{p}81.25 ± 0.01^{ab}
		35	81.27 ± 0.01	^{p}79.36 ± 0.01^{abc}	^{pq}78.29 ± 0.01^{abc}
pH value		-20	6.29 ± 0.01	6.29 ± 0.02	6.29 ± 0.01
		4	6.29 ± 0.01	6.28 ± 0.01	6.28 ± 0.01
		25	6.29 ± 0.01	6.29 ± 0.01	6.27 ± 0.01
		35	6.29 ± 0.01	6.28 ± 0.02	6.28 ± 0.02

[a] $p<0.05$ as compared to storage temperature -20°C
[b] $p<0.05$ as compared to storage temperature 4°C
[c] $p<0.05$ as compared to storage temperature 25°C
[p] $p<0.05$ as compared to storage duration 0 month
[q] $p<0.05$ as compared to storage duration 3 months

health perspective, the ability to bind oil or bile acids and their increasing excretion is linked to plasma cholesterol reduction (Lan et al. 2012). High OHC might be attributed to IDF content of PSC powder as it can absorb oil (Raghavendra et al. 2006). Besides the chemical factors, physical factors (drying and grinding PSC into powder) resulted in larger surface area, thus improving absorption, resulting in high WHC, SWC and OHC (Lan et al. 2012).

The emulsifying ability (EA) can be defined as the ability of a molecule to act as an agent that aids in solubilisation or dispersion of two immiscible liquids. Emulsifying stability (ES) is the capability to maintain the emulsion integrity. Basically, PSC powder possesses high EA (51.67%) and ES (95.37%) which could be utilized in foods requiring emulsion formation and extended shelf life. High protein content of PSC powder could explain the result as most proteins are recognized as strong emulsifying agents (Viuda-Martos et al. 2012).

Table 3 documented the changes of physicochemical properties of PSC in relation to the factors of storage temperature and duration. This study demonstrated that moisture contents decrease significantly (p<0.05) proportional to the increasing storage temperature, with 35°C recorded the lowest (6.94% moisture) and -20°C recorded the highest (7.19% moisture) after 6 months of storage. The trend of result is supported by (Zhou et al. 2014). Furthermore, moisture content was also influenced by different storage time intervals in which 6 months of storage documented more significant (p<0.05) moisture results than to that of 3 months in comparison to the initial (0 month) readings. Water activity (A_w) refers to water in food that is not adhered to food molecules and can facilitate the growth of bacteria, yeast and mould. It was increased significantly (p<0.05) with increment of storage temperature and duration, with PSC powder stored at 35°C for 6 months being reported with the highest value (0.47). However, storage temperature of -20 and 4°C maintained their initial water activity level of 0.42 throughout the study.

Colour is one of the essential quality parameters of foods as its changes may imply modification of the nutritional and organoleptic properties of foods. Both storage temperature and duration affected the optical properties (Lightness L*, redness a*, yellowness b*) of PSC powder. With increasing storage temperature, PSC powder reported significantly (p<0.05) lower L* value but higher a* and b* value. Moreover, longer storage duration brought more significant impacts on optical properties. Reduced L* value at higher storage temperature mainly due to Maillard browning reaction which taken place in higher water activity level (Stapelfeldt et al. 1997). Lower L* value can affect the overall acceptability of PSC powder. This finding is in line with Rao et al. (2013) who demonstrated lower L* value of hen egg white powder with increasing storage temperature. In term of pH value, it did not show difference (p>0.05) in the aspect of both storage temperature and duration. It may due to absence of microbial proliferation. For a food to have an extended shelf-life, it is required to control its acidity (pH) and water activity level.

The microbial content of PSC powder at different levels of storage temperature and duration are presented in Table 4. In general, total plate count (TPC) as well as yeast and mould count (YMC) in PSC powder showed slight increment with increasing storage temperature and duration, but there was negligible difference (p>0.05). TPC of PSC powder was ranged from 5.39 to 5.49 log CFU/mL whereas YMC of PSC powder was ranged from 2.67 to 2.75 log CFU/mL within both storage temperatures and storage duration. Microbial proliferation is only possible in foods with A_w value higher than 0.50. Since the A_w in this study was in the range of 0.42 to 0.47, microbial growth was not occurred and thus did not jeopardize PSC powder shelf life. The same trends of indifferent in microbial counts were documented in orange by-products powder with A_w value range from 0.26 to 0.45 (Fernández-López et al. 2009).

Conclusion

PSC has high quantity of nutritional contents such as protein, ash and most importantly dietary fibre and β-glucan but low in sucrose, calorific value and fat content. Besides, it has excellent functional properties such as water

TABLE 4. Effect of storage temperature and duration on microbial contents of PSC powder (mean ± SD)

Microbial content	Storage temperature (°C)	Total plate count and yeast and mould count (log CFU/mL)		
		Storage duration (months)		
		0	3	6
Total plate count	-20	5.39 ± 0.16	5.40 ± 0.07	5.42 ± 0.14
	4	5.39 ± 0.16	5.41 ± 0.27	5.42 ± 0.27
	25	5.39 ± 0.16	5.45 ± 0.35	5.47 ± 0.31
	35	5.39 ± 0.16	5.44 ± 0.42	5.49 ± 0.40
Yeast and mould count	-20	2.67 ± 0.17	2.68 ± 0.36	2.72 ± 0.17
	4	2.67 ± 0.17	2.70 ± 0.32	2.72 ± 0.24
	25	2.67 ± 0.17	2.69 ± 0.34	2.74 ± 0.19
	35	2.67 ± 0.17	2.70 ± 0.27	2.75 ± 0.24

holding capacity, oil holding capacity, swelling capacity and emulsifying activity. From the storage stability study, PSC powder exhibited lower moisture content and L* colorimetric value while higher water activity level was observed with increasing storage temperature but no significant difference in pH value and microbial counts were detected. The storage temperatures at -20, 25 and 35°C jeopardized the original colour properties of PSC powder which can be easily visible by the naked eyes. Hence, the most suitable storage temperature of PSC powder is 4°C. Overall, based on nutritional, functional and microbial properties, PSC powder is a potentially safe and multifunctional dietary fibre rich ingredient in food application.

ACKNOWLEDGEMENTS

The authors acknowledge Research University Grant (Grant no: 1001/PPSK/813057) for providing financial assistance. We are also thankful to the contributions from the staff members of the nutrition lab in the School of Health Sciences and the School of Industrial Technology, Universiti Sains Malaysia in completing the study.

REFERENCES

Abdul-Hamid, A. & Luan, Y.S. 2000. Functional properties of dietary fibre prepared from defatted rice bran. *Food Chemistry* 68(1): 15-19.

Agrawal, R.P., Chopra, A., Lavekar, G.S., Padhi, M.M., Srikanth, N., Ota, S. & Jain, S. 2010. Effect of oyster mushroom on glycemia, lipid profile and quality of life in Type 2 diabetic patients. *Australian Journal of Medical Herbalism* 22(2): 50-54.

AOAC. 1996. *Official Methods of Analysis of AOAC International*. 16th ed. Maryland USA: AOAC International.

AOAC. 1990. *Total Dietary Fibre in Foods. Enzymatic-Gravimetric Method*. 15th ed. The Association: Arlington, VA: Official Methods of Analysis of AOAC International.

Bosaeus, I. 2004. Fibre effects on intestinal functions (diarrhoea, constipation and irritable bowel syndrome). *Clinical Nutrition Supplements* 1(2): 33-38.

Chau, C.F. & Huang, Y.L. 2003. Comparison of the chemical composition and physicochemical properties of different fibers prepared from the peel of *Citrus sinensis* L. Cv. Liucheng. *Journal of Agricultural and Food Chemistry* 51(9): 2615-2618.

Chau, C.F., Cheung, P.C.K. & Wong, Y.S. 1997. Functional properties of protein concentrate from three Chinese indigenous legume seeds. *Journal of Agricultural and Food Chemistry* 45: 2500-2503.

Czapski, J. & 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.

Elleuch, M., Bedigian, D., Roiseux, O., Besbes, S., Blecker, C. & Attia, H. 2011. Dietary fibre and fibre-rich by-products of food processing: Characterisation, technological functionality and commercial applications: A review. *Food Chemistry* 124: 411-421.

Fernández-López, J., Sendra-Nadal, E., Navarro, C., Sayas, E., Viuda-Martos, M. & Alvarez, J.A.P. 2009. Storage stability of a high dietary fibre powder from orange by-products. *International Journal of Food Science & Technology* 44(4): 748-756.

Gormley, T.R. 1975. Chill storage of mushrooms. *Journal of the Science of Food and Agriculture* 26: 401-411.

Grigelmo-Miguel, N. & Martı´n-Belloso, O. 1999. Comparison of dietary fibre from by-products of processing fruits and greens and from cereals. *LWT-Food Science and Technology* 32(8): 503-508.

Guillon, F. & Champ, M. 2000. Structural and physical properties of dietary fibres, and consequences of processing on human physiology. *Food Research International* 33(3-4): 233-245.

Kaczmarczyk, M.M., Miller, M.J. & Freund, G.G. 2012. The health benefits of dietary fiber: Beyond the usual suspects of Type 2 diabetes mellitus, cardiovascular disease and colon cancer. *Metabolism* 61(8): 1058-1066.

Lan, G., Chen, H., Chen, S. & Tian, J. 2012. Chemical composition and physicochemical properties of dietary fiber from *Polygonatum odoratum* as affected by different processing methods. *Food Research International* 49(1): 406-410.

Lario, Y., Sendra, E., García-Pérez, J., Fuentes, C., Sayas-Barberá, E., Fernández-López, J. & Pérez-Alvarez, J.A. 2004. Preparation of high dietary fibre powder from lemon juice by-products. *Innovative Food Science and Emerging Technology* 5: 113-117.

Lin, M.J.Y., Humbert, E.S. & Sosulski, F.W. 1974. Certain functional properties of sunflower meal products. *Journal of Food Science* 39: 368-370.

López-Vargas, J.H., Fernández-López, J., Pérez-Álvarez, J.A. & Viuda-Martos, M. 2013. Chemical, physico-chemical, technological, antibacterial and antioxidant properties of dietary fiber powder obtained from yellow passion fruit (*Passiflora edulis* var. flavicarpa) co-products. *Food Research International* 51(2): 756-763.

McCleary, B.V. & Glennie-Holmes, M. 1985. Enzymic quantification of (1-3)(1-4)-β-D-glucan in barley and malt. *Journal of the Institute of Brewing* 91: 285-295.

Miles, P.G. & Chang, S.T. 1997. *Mushroom Biology: Concise Basics and Current Development*. New York: World Scientific Publishing Company.

Patrabansh, S. & Madan, M. 1997. Studies on cultivation, biological efficiency and chemical analysis of *Pleurotus sajor-caju* (FR.) Singer on different bio-wastes. *Acta Biotechnology* 17(2): 107-122.

Pinero, M.P., Parra, K., Huerta-Leidenz, N., de Moreno, L.A., Ferrer, M., Araujo, S. & Barboza, Y. 2008. Effect of oat's soluble fibre (β-glucan) as a fat replacer on physical, chemical, microbiological and sensory properties of low-fat beef patties. *Meat Science* 80: 675-680.

Raghavendra, S.N., Ramachandra Swamy, S.R., Rastogi, N.K., Raghavarao, K.S.M.S., Kumar, S. & Tharanathan, R.N. 2006. Grinding characteristics and hydration properties of coconut residue: A source of dietary fiber. *Journal of Food Engineering* 72(3): 281-286.

Rao, Q., Rocca-Smith, J.R. & Labuza, T.P. 2013. Storage stability of hen egg white powders in three protein/water dough model systems. *Food Chemistry* 138(2-3): 1087-1094.

Robertson, J.A., de Monredon, F.D., Dysseler, P., Guillon, F., Amado, R. & Thibault, J.F. 2000. Hydration properties of dietary fibre and resistant starch: A European collaborative study. *LWT - Food Science and Technology* 33(2): 72-79.

Shah, S., Ghosh, D., Mallick, S.K., Sarangi, I., Bhutia, S.K., Banerje, I. & Maiti, T.K. 2007. Immunomodulatory and antitumor activities of water-soluble proteoglycan isolated

from the fruiting bodies of culinary-medicinal oyster mushroom *Pleurotus ostreatus*. *International Journal of Medicinal Mushroom* 9: 123-138.

Stapelfeldt, H., Nielsen, B.R. & Skibsted, L.H. 1997. Effect of heat treatment, water activity and storage temperature on the oxidative stability of whole milk powder. *International Dairy Journal* 7(5): 331-339.

Viuda-Martos, M., Ruiz-Navajas, Y., Martin-Sánchez, A., Sánchez-Zapata, E., Fernández-López, J., Sendra, E., Sayas-Barberá, E., Navarro, C. & Pérez-Álvarez, J.A. 2012. Chemical, physico-chemical and functional properties of pomegranate (*Punica granatum* L.) bagasses powder co-product. *Journal of Food Engineering* 110(2): 220-224.

Wan Rosli, W.I., Nurhanan, A.R. & Aishah, M.S. 2012. Effect of partial replacement of wheat flour with oyster mushroom (*Pleurotus sajor-caju*) powder on nutritional composition and sensory properties of butter biscuit. *Sains Malaysiana* 41(12): 1565-1570.

Wasser, S.P. 2002. Medicinal mushrooms as a source of antitumor and immonomudulating polysaccharides. *Applied Microbiology and Biotechnology* 60: 258-274.

Zhou, P., Liu, D., Chen, X., Chen, Y. & Labuza, T.P. 2014. Stability of whey protein hydrolysate powders: Effects of relative humidity and temperature. *Food Chemistry* 150: 457-462.

Ng Sze Han & Wan Rosli Wan Ishak*
Nutrition Program, School of Health Sciences
Universiti Sains Malaysia Health Campus
16150 Kubang Kerian, Kelantan Darul Naim
Malaysia

Wan Amir Nizam Wan Ahmad
Biomedicine Program, School of Health Sciences
Universiti Sains Malaysia Health Campus
16150 Kubang Kerian, Kelantan Darul Naim
Malaysia

*Corresponding author; email: wrosli@usm.my

Received: 5 May 2015
Accepted: 21 March 2016