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FULL PAPER

Physicochemical properties of chili padi Centil (*Capsicum frutescens*) powder dried at different drying temperatures

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Abstract

This study addressed selected drying temperatures in extending the shelf life of local chili padi Centil (*Capsicum frutescens*) powder with better physicochemical properties. The effects of drying at different temperatures (50˚C, 60˚C, and 70˚C) on chili padi Centil powder was evaluated through its functional properties, including moisture content, color, water holding capacity, oil holding capacity and water solubility index as well as total phenolic content determination. Chili padi Centil powder dried at 70˚C had permitted level of moisture content (10.38%). Drying treatment at 70˚C also produced significantly smaller particle size powder (1301.1821 μm) with higher water holding capacity (2.67%), oil holding capacity (1.3%) and water solubility index (7.65%) compared to chili padi Centil dried at 50˚C and 60˚C. The powder dried at 50˚C and 70˚C showed significant visible color difference where 50˚C drying temperature resulted in intense red color powder whereas 70˚C drying temperature resulted in degraded orange color powder. The drying treatment significantly degraded the total phenolic content of chili powder.

1. Introduction

Chili is a type of herb that belongs to the genus Capsicum, under the family Solanaceae. It is a native fruit originated from America and later introduced into Europe, Africa and Asia by Christopher Columbus (Kollmannsberger *et al.,* 2011; Giufrrida *et al.,* 2013). There are five major species of Caspsicum which include *Capsicum frutescens, Capsicum annuum, Capsicum chinense, Capsicum baccatum* and *Capsicum pubescens* each distinguished by their own trait, color, aroma and pungency level (Kollmannsberger *et al.,* 2011). In Malaysia, *Capsicum annuum* and *Capsicum frutescence* are widely grown and used by locals as one of many cooking ingredients or consumed as fresh vegetables. One of a common chili cultivate in Malaysia is Chili padi Centil, a type classified under *Capsicum frutescence* that is small in size and has a strong pungent smell. Its size ranges from 2 to 3 cm and it contains nutrients including minerals, vitamins and phytochemicals such as flavonoids, phenolic acids, carotenoids and capsaicinoids that act as health-promoting components in consumers' diet (Jayaprakasha *et al.,* 2012; Ogunlade *et al.,* 2013).

Chili is popularly known for its hot and spicy flavor, thus suitable to be used for culinary purposes, spice to dishes and sauces and also as a condiment in cooking (Ogunlade *et al*., 2013). The spicy flavor is due to the presence of capsaicinoids which accumulate in the placenta of Capsicum species (Juangsamoot *et al.,* 2012). Fresh chili has a short shelf life due to its high moisture content (more than 40%), thus chili has also been made into various forms include dried, flakes, paste and powder to extend its shelf life by the food manufacturing companies mainly through drying process.

Drying is one of the common preservation methods that will inhibit or slow down microbial growth and certain biochemical changes within the plant tissue, altering the plant's aroma and appearance (Kubra and Rao, 2012). Traditional drying involves exposing the chilies under open air and sunlight which is considered as time-consuming and not contamination free (Condori *et al*., 2001). Alternative drying method such as hot air drying offers a shorter drying time with uniform heating and more hygienic. Toontom *et al*. (2012) reported that the temperature needed to achieve approximately 10% of moisture content ranges between 50°C to 70°C. However, thermal process such as drying significantly affect the visual and nutritional quality of chili. A study was done on the effect of thermal treatment on bioactive compounds in green chili (*Capsicum annum*) powder found that the vitamin C content of the powder has reduced approximately 50% (from 110 mg/ 100 g to

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59.08 mg/ 100 g) due to thermal processing (Sarker *et al*., 2013). Since different species compose of different proximate composition, the drying temperature that is compatible for each species is different and need to be adequately specified.

This study is aimed to determine the composition of local chili padi Centil and characterize the powders dried at different drying temperatures. This is important to produce shelf-life stable chili powder with minimum discoloration to meet consumer's demand.

2. Materials and methods

2.1 Sample preparation and drying process

Fresh chili padi Centil (*Capsicum frutescence*) was collected from Agro Sembilan Belas farm at Batu Pahat, Johor. The color and degree of maturity of chili were selected according to the Malaysia Agricultural Commodity and Food Standards (2016). The chilies were washed and their pods were removed, then blanched in 100°C of boiling water for 6 mins (Aminah and Permatasari, 2013). The blanched chilies were cut vertically and oven-dried using different temperatures of 50°C (B), 60°C (C) and 70°C (D) for 4 hrs and 30 mins. Fresh chili padi Centil that did not undergo any processing was used as control (A). The dried chilies were ground for 3 mins into powder, weighed and stored in polypropylene bag at -20°C for further analysis.

2.2 Moisture content

The moisture content of chili powders (A, B, C and D) was done according to the standard Official Methods of Analysis (Association of Official Analytical Chemists (AOAC), 2006).

2.3 Determination of color

The fresh chili padi Centil and dried chili padi Centil powder was spread out in a transparent zipper bag (5cm by 5cm) for color measurement using chroma meter CR-410. Instrumental color data was provided by the CIE system in terms of L*(lightness), a*(redness and greenness) and b*(yellowness and blueness) (Pathare *et al*., 2012).

2.4 Determination of particle size

The particle size of chili padi Centil powder was determined using a particle size analyzer according to methods described by Phat *et al*. (2015).

2.5 Determination of water and oil holding capacity

Water holding capacity (WHC) and oil holding capacity (OHC) of chili padi Centil powder were determined using the method described by Zhang *et al.* (2012).

2.6 Determination of water solubility index

Water solubility index (WSI) of chili padi Centil powder was determined using the method described by Zhang *et al*. (2012). A 5 g of chili powder was added into a centrifuged tube containing 10 mL distilled water at ambient temperature. The dispersion was placed in a water bath at 80°C for 30 mins, followed by centrifugation at 6000 rpm for 10 mins. The supernatant was carefully collected in a pre-weighed evaporating dish and left to dry at 105˚C. The evaporating dish with residue was weighed. The WSI was calculated using Equation 1.

$$WSI = \frac{Dried\,supernatant\,(g)}{Sample\,powder\,(g)} \times 100\%$$

2.7 Determination of total phenolic content

Extraction of total phenolic content from chili padi Centil powder was done according to the method described by Alam *et al.* (2015) with some modifications. Approximately 2 g powders were mixed with 20 mL methanol and incubated in 40°C water bath shaker for 2 hrs. The supernatant was collected using filter paper and the residue was extracted again. The supernatants were pooled together and subjected to a rotary evaporator. The concentrated extract was stored at −20°C for further analysis.

The total phenolic content (TPC) was determined using the Folin-Ciocalteu method described by Alam *et al.* (2015). Approximately 0.5 mL extract was mixed with 0.5 mL Folin-Ciocalteu reagent and 10 mL of 7% Na_2CO_3 solution. The mixture was incubated for 1 hr at 25°C in the dark. The absorbance was measured at 765 nm using a UV–vis spectrophotometer. The amount of TPC was expressed as milligram of Gallic acid equivalents (GAE) per g of sample (mg GAE*g−1 DW).

2.8 Statistical analysis

All results were expressed as mean ± standard deviation (SD) and statistics were performed using Minitab version 17 statistical package. One-way analysis of variance (ANOVA) and Turkey's multiple comparison tests were used to determine the significant difference between the different drying temperatures on chili padi powder when the calculated p-value is lower than 0.05.

3. Results and discussion

3.1 Moisture content and effect of drying

Table 1 shows the moisture content of fresh chili padi Centil and dried chili padi Centil powders after drying process at different temperatures. Based on preliminary study, the drying temperatures were chosen from 50˚C, 60˚C, 70˚C at a fixed time to achieve approximately 10% moisture content. The highest drying temperature took the shortest time to dry and achieved moisture content up to 10%. Following the kinetic theory, an increase in temperature can cause the energy molecules to increase. The higher state of energy allowed the water molecules to escape easier and faster from the product, resulting in shorter drying time (Maskan *et al.,* 2002). The moisture content of chili powder should be in the range of 8-10% per 100 g. According to Indian Standard, the maximum moisture content for chili powder is 11% and values higher than 15% was critical with respect to mold growth (Mamun, 2016).

Table 1. Moisture content of fresh chili padi Centil and dried chili padi Centil powders at different drying temperatures.

Type of sample	Moisture content (%)
A	74.32±0.25[a]
B	39.09±0.57[b]
C	10.91±0.05[c]
D	10.38±0.09[c]

Each value is Mean ± Standard Deviations. The test values along the same column carrying different superscripts are significantly different (p<0.05). A=fresh chili padi, B=dried at 50˚C, C=dried at 60˚C, D=dried at 70˚C.

3.2 Color

Table 2 presents the color values of fresh chili padi Centil and dried chili padi Centil powders after drying process at different temperatures. L* and a* values are very important in order to observe the changed and the degradation of chili padi Centil powder color after drying process. From the results, it is observed that L* and a* values differ significantly for every sample treated at different drying temperatures. The different drying temperatures significantly affect the color of chili padi Centil powder, whereby high drying temperature produces orange chili padi Centil powder with low L* and a* values. The red color of chili comes from the red-pigmented carotenoids including capsanthin, casorubin, zeaxanthin and cryptoxanthin which are all very stable in intact tissue plant. However, the subjection of plant tissue to friction and heat during grinding and drying causes the carotenoids to easily auto-oxidize. The reaction leads to a more orange (Figure 1 (a) and (b)) and less intense coloration that devalues the spice powder (Gupta *et al.,* 2017). The chili powder dried at the lowest temperature (50˚C) showed intense in red color while chili powder at highest temperature (70˚C) showed less intense in red color where it degraded into orange color.

Table 2. Color determination of fresh chili padi Centil and dried chili padi Centil powders at different drying temperatures.

Type of sample	Color measurement		
	L*	a*	b*
A	73.14±1.33[a]	33.32±1.26[a]	26.38±1.14[a]
B	55.06±0.04[b]	32.17±0.07[b]	27.40±0.02[b]
C	53.00±0.46[c]	29.82±0.02[c]	27.59±0.06[b]
D	52.08±0.54[d]	25.19±0.37[d]	24.18±0.04[c]

Each value is Mean ± Standard Deviations. The test values along the same column carrying different superscripts are significantly different (p<0.05). L*(lightness), a* (+a*=redness, -a*=greenness), b*(+b*=yellowness, -b*=blueness). A=fresh chili padi, B=dried at 50˚C, C=dried at 60˚C, D=dried at 70˚C.

(a) (b)

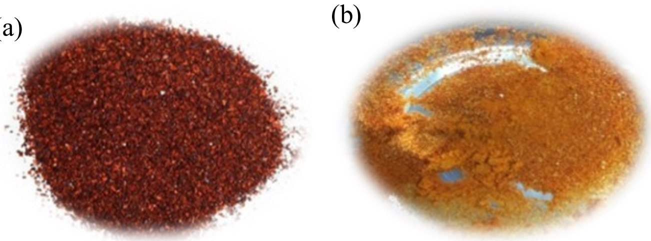

Figure 1. Chili padi Centil powder dried at (a) 50°C and (b) 70°C

3.3 Particle size

Table 3. Particle size determination of dried chili powders at different drying temperatures.

Type of sample	Particle size (μm)
B	3187.33[a]
C	1491.23[b]
D	1301.18[c]

Each value is Mean ± Standard Deviations. The test values along the same column carrying different superscripts are significantly different (p<0.05). B=dried at 50˚C, C=dried at 60˚C, D=dried at 70˚C.

Based on Table 3, the chili dried at 70˚C had the smallest value of particle size compared to other dried chili powders. The different moisture content of the dried chili after drying at different temperatures could have an effect on the performance of the grinding process (Jung *et al.,* 2018). Powders with lower moisture content are harder and more brittle, thus less resistant to grinding process (Lee *et al.,* 2014). According to Moon and Yoon (2018), the grinding kinetics model of powder assumes the force of aggregation of each particle during grinding is zero, however, in a high moisture content powder, agglomeration is highly expected to happen which disrupt the grinding process, thus producing larger particle size powder. The lowest moisture content of sample D may be caused by the high temperature exerted during the drying process, thus less energy is required to grind the chili into smaller powder size (Moon and

Yoon, 2017). A similar report was narrated on the relationship between low moisture content influenced a shorter grinding process time which produced finer or smaller particle size of kernel wheat powder and black soybean powder (Walde *et al.,* 2002; Lee *et al.,* 2014).

3.4 Water holding capacity, oil holding capacity and water solubility index

Based on Table 4, the ability of chili padi Centil powder to retain water and oil increased as the particle size decreased. Water and oil holding capacities are important functional properties. Oil holding capacity influences textural and sensory attributes of food (Haque *et al*., 2016). The water holding capacity involves a protein-water interaction in the food system (Damodaran and Paraf, 1997). It affects the texture, juiciness, taste and the shelf life of bakery products (Jideani, 2011). The heating treatment applied on food can either reduce the availability of polar amino groups for hydrogen bonding with water molecules by enzyme denaturation or improve water holding capacity by unfolding and exposing the side protein side chains to bind with water molecules (Cheftel *et al.,* 1985). The smallest particle sized powder may have the largest surface area for reaction to occur and more hydraulic groups of chili powder exposed causing an easier integration of powder with water (Zhao *et al.,* 2011). The water solubility index of chili powder also the highest when the particle size is the smallest. The finer particle sized powders have more ability and stability to be mixed with other spices or ingredients (Zhao *et al*., 2011).

Table 4. Water holding capacity, oil holding capacity and water solubility index of dried chili padi Centil powders at different drying temperatures.

Type of sample	WHC (%)	OHC (%)	WSI (%)
B	$1.79{\pm}0.52^a$	$1.12{\pm}0.07^a$	$5.96{\pm}0.64^a$
C	$1.98{\pm}0.28^b$	$1.24{\pm}0.09^a$	$6.57{\pm}0.3^a$
D	$2.67{\pm}0.38^c$	$1.30{\pm}0.06^b$	$7.65{\pm}0.68^b$

Each value is Mean ± Standard Deviations. The test values along the same column carrying different superscripts are significantly different ($p<0.05$). Where; WHC = Water Holding Capacity; OHC = Oil Holding Capacity, WSI = Water Solubility Index. B=dried at 50˚C, C=dried at 60˚C, D=dried at 70˚C.

3.5 Total phenolic content

Total phenolic content is an assay to assess the amount of phenolic content in a sample which contributes to the functional properties of the food. Previous studies reported a strong and positive correlation ($p\leq0.05$) between the total phenolic compound contents and the antioxidant potential of fruits and vegetables (Reddy et al., 2010). Food containing antioxidative compounds reduces lipid oxidation in animal tissues, therefore decreasing the risk of potential oxidative stress-based diseases (Eliassen *et al.,* 2012; Tanaka *et al.,* 2012; Pojer *et al.,* 2013).

Based on Table 5, the fresh chili showed sample D showed the lowest phenolic content as compared to others. Deepa *et al.* (2005) reported that the high thermal treatment subjected during drying process may disrupt the cell compartments and causing enzymatic degradation that leads to the reduction of phenolic content. The high thermal treatment applied can cause degradation of the thermal-labile compounds including phenolic compounds (Baharuddin *et al.,* 2018).

Table 5. Total phenolic content of fresh chili padi Centil and dried chili padi Centil powders at different drying temperatures.

Type of sample	TPC (mg GAE/ kg)
A	0.899 ± 0.060^a
B	0.842 ± 0.014^a
C	0.698 ± 0.010^b
D	0.584 ± 0.004^c

Each value is Mean ± Standard Deviations. The test values along the same column carrying different superscripts are significantly different ($p<0.05$). A=fresh chili padi, B=dried at 50˚C, C=dried at 60˚C, D=dried at 70˚C.

4. Conclusion

The application of drying treatment at temperature starting from 60˚C can produce chili padi Centil powder with required 10% moisture content, reducing the potential of microorganism growth, thus extending its shelf life. The drying treatment at 70˚C produced chili padi Centil powder with the highest water holding capacity of 2.67%, oil holding capacity of 1.3% and water solubility index of 7.65% which promotes the powder's solubility, enhancing its application efficiency. However, further study should be conducted to overcome the less intense orange color produced which is less preferred by consumers and the degradation of total phenolic content resulted from the thermal treatment.

Conflict of Interest

The authors declare no conflict of interest.

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References

Alam, M.A., Mahmod, N.H., Syazwanie, N.F., Badaluddin, N.A., Mustafa, K.A., Alias, N., Aslani,

F. and Prodhan, A. (2018). Evaluation of antoxidant compounds, antioxidant activites and capsaicinoid compounds of Chili (*Capsicum* sp.) germplasms available in Malaysia. *Journal of Allied Research on Medicinal and Aromatic Plants*, 9, 46-54. https://doi.org/10.1016/j.jarmap.2018.02.001

Aminah, A. and Permatasari, K.A. (2013). Effect of drying and cooking methods on antioxidant properties of bitter gourd (*Momordica charantia*). *Journal of Tropical Agriculture and Food Science,* 41(2), 249-256.

Association of Official Analytical Chemists (AOAC). (2006). Official Methods of Analysis of the Association of Official Analytical Chemist. 16th ed. Washington: The Association of Official Analytical Chemists.

Baharuddin, N.A.F., Nordin, M.F.M., Morad, N.A., Aris, N.I.A., and Yunus, M.A.C. (2018). Total phenolic, flavonoid content and antioxidant activity of *Clinacanthus nutans* leaves by water-based ultrasonic assisted extraction. *Malaysian Journal of Analytical Sciences,* 22(4), 659-666. https://doi.org/10.17576/mjas-2018-2204-12

Cheftel, J.C., Cuq, J.L. and Lorient, D. (1985). Amino acids, peptides, and proteins. In Fennema, O.R. (Ed.). Food Chemistry, p. 245-369. New York: Marcel Dekker, Inc.

Condori, M., Echazu, R. and Saravia, L. (2001). Solar drying of sweet pepper and garlic using the tunnel greenhouse drier. *Renewable Energy*, 22, 447-460. https://doi.org/10.1016/S0960-1481(00)00098-7

Damodaran, S. and Paraf, A. (1997). Food proteins and their applications. New York: Marcel Dekker.

Eliassen, A.H., Hendrickson, S.J., Brinton, L.A., Buring, J.E., Campos, H., Dai, Q., Dorgan, J.F., Franke, A.A., Gao, Y., Goodman, M.T., Hallmans, G., Helzlsouer, K.J., Hoffman-Bolton, J., Hultén, K., Sesso, H.D., Sowell, A.L., Tamimi, R.M., Toniolo, P., Wilkens, L.R., Winkvist, A., Zeleniuch-Jacquotte, A., Zheng, W. and Hankinson, S.E. (2012). Circulating carotenoids and risk of breast cancer: Pooled analysis of eight prospective studies. *Journal of the National Cancer Institute,* 104(19), 1905-1916. https://doi.org/10.1093/jnci/djs461

Giufrrida, D., Dugo, P., Torre, G., Bignardi, C., Cavazza, A., Corradini, C. and Dugo, G. (2013). Characterization of 12 Capsicum varieties by evaluation of their carotenoid profile and pungency determination. *Food Chemistry,* 140(4), 794-802. https://doi.org/10.1016/j.foodchem.2012.09.060

Gupta, R.C., Aqil, F., Jeyabalan, J., Munagala, R., Ravoori, S., Vadhanam, M.V. and Schultz, D.J. (2017). Chemoprevention of rat mammary carcinogenesis by Apiaceae spices, *International of Molecular Science,* 18(2), 425. https://doi.org/10.3390/ijms18020425

Haque, A., Prasad, T.Y. and Benu, A. (2016). Food proteins, structure and function. *Reference Module in Food Science.* https://doi.org/10.1016/B978-0-08-100596-5.03057-2

Jayaprakasha, G.K., Bae, H., Crosby, K. and Jifon, J. (2012). Bioactive compounds in peppers and their antioxidant potential. *ACS Symposium Series,* 1109, 43-56. https://doi.org/10.1021/bk-2012-1109.ch004

Jideani, V.A. (2011). Functional properties of soybean food ingredients in food systems. *Soybean Biochemistry, Chemistry and Physiology.* InTech Open E-Book. https://doi.org/10.5772/14668

Juangsamoot, J., Chanthai, S., Ruangviriyachai, C. and Techawongstien, S. (2012). Determination of capsaicin and dihydrocapsaicin in some chili varieties using accelerated solvent extraction associated with solid-phase extraction methods and RP-HPLC-Fluorescence. *E-Journal of Chemistry,* 9 (3), 1550-1561. https://doi.org/10.1155/2012/380574

Jung, H., Lee, Y.J. and Yoon, W.B. (2018). Effect of moisture content on the grinding process and powder properties in food: A review. *Processes,* 6(6), 69. https://doi.org/10.3390/pr6060069

Kollmannsberger, H., Rodriguez-Burruezo, A., Nitz, S. and Nuez, F. (2011). Volatile and capsaicinoid composition of aji (*Capsicum baccatum*) and rocoto (*Capsicum pubescens*), two Andean species of chile peppers. *Journal of the Science of The Food and Agriculture,* 91(9), 1598-1611. https://doi.org/10.1002/jsfa.4354

Kubra, I.R. and Rao, L.J.M. (2011). An impression on current developments in the technology, chemistry and biological activities of ginger (*Zingiber officinale* Roscoe). *Critical Reviews in Food Science and Nutrition,* 52(8), 651-688. https://doi.org/10.1080/10408398.2010.505689

Lee, Y.J., Yoo, J.S. and Yoon, W.B. (2014). Grinding characteristics of black soybeans (Glycine max) at varied moisture contents: particle size, energy consumption and grinding kinetics. *International Journal of Food Engineering,* 10(3), 347-356. https://doi.org/10.1515/ijfe-2014-0017

Mamun, A.A. (2016). Quality assessment of selected commercial brand of chili powder in Bangladesh. *MOJ Food Processing and Technology,* 3(2), 291-294. https://doi.org/10.15406/mojfpt.2016.03.00070

Maskan, A., Kaya, S. and Maskan, M. (2002). Hot air and sun drying of grape leather. *Journal of Food*

Engineering, 54(1), 81-88. https://doi.org/10.1016/S0260-8774(01)00188-1

Moon, J.H. and Yoon, W.B. (2018). Effect of moisture content and particle size on grinding kinetics and flowability of balloon flower (*Platycodon grandiflorum*). *Food Science and Biotechnology,* 27 (3), 641-650. https://doi.org/10.1007/s10068-017-0291-z

Ogunlade, I., Alebiosu, A.A. and Osasona, A.I. (2013). Proximate, mineral composition, antioxidant activity and total phenolic content of some pepper varieties (Capsicum species). *International Journal of Biological and Chemical Sciences,* 6, 1-7. https://doi.org/10.4314/ijbcs.v6i5.28

Pathare, P.B., Al-Said, F.A.J. and Opara, U.M. (2013). Color measurement and analysis in fresh and processed food: A review. *Food and Bioprocess Technology,* 6(1), 36-60. https://doi.org/10.1007/s11947-012-0867-9

Phat, C., Hua, L., Lee, D.U., Moon, B.K. and Chan, L. (2015). Characterization of *Hericum erinaceum* powders prepared by conventional roll milling and jet milling. *Journal of Food Engineering*, 145, 19-24. https://doi.org/10.1016/j.jfoodeng.2014.08.001

Pojer, E., Mattivi, F., Johnson, D. and Stockley, C.S. (2013). The case of anthocyanin consumption to promote human health: A review. *Comprehensive Reviews in Food Science and Food Safety,* 12(5), 483-508. https://doi.org/10.1111/1541-4337.12024

Sarker, N., Islam, S., Hasan, M., Kabir, F., Uddin, M.A. and Noor, R. (2013). Use of multiplex PCR assay for detection of diarrheagenic *Escherichia coli* in street vended food items. *American Journal of Life Sciences*, 1(1), 267-272. https://doi.org/10.11648/j.ajls.20130106.15

Tanaka, T., Shnimizu, M. and Moriwaki, H. (2012). Cancer chemoprevention by carotenoids. *Molecules,* 17(3), 3202-3242. https://doi.org/10.3390/molecules17033202

Toontom, N., Meenune, M., Posri, W. and Lertsiri, S. (2012). Effect of drying method on physical and chemical quality, hotness and volatile flavor characteristics of dried chili. *International Food Research Journal*, 19(3), 1023-1031.

Walde, S. G, Balaswamy, K., Velu, V. and Rao, D.G. (2002). Microwave drying and grinding characteristics of wheat (*Triticum aestivum*). *Journal of Food Engineering,* 55(3), 271-276. https://doi.org/10.1016/S0260-8774(02)00101-2

Zhang, Z., Song, H., Peng, Luo, Q., Ming, J. and Zhao, G. (2012). Characterization of stipe and cap powders of mushroom (*Lentinus edodes*) prepared by different grinding methods. *Journal of Food Engineering,* 109(3), 406-413. https://doi.org/10.1016/j.jfoodeng.2011.11.007

Zhao, X., Yang, Z.B., Yang, W.R., Wang, Y., Jiang, S.Z. and Zhang, G.G. (2011). Effects of ginger root (*Zingiber officinale)* on laying performance and antioxidant status of laying hens and on dietary oxidation stability. *Poultry Science,* 90(8), 1720-1727. https://doi.org/10.3382/ps.2010-01280

