Advance Journal of Food Science and Technology 11(9): 619-624, 2016
DOI:10.19026/ajfst.11.2738
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: August 17, 2015 Accepted: September 12, 2015 Published: July 25, 2016

Research Article

Study on the Prediction Models for the Browning Degree of the Postharvest Agaricus Bisporus based on Color Parameters

Hu Yunfeng, LiuYunyun, Liu Guohua, Chen Yuanyuan and Su Li
Key Laboratory of Food Nutrition and Safety, Ministry of Education, Tianjin University of Science and Technology, Tianjin 300457, China

Abstract: Browning is one of the most important factors affecting the quality of postharvest agaricus bisporus. In the study, the changing rules of L*, a*, b* value and Browning Degree (BD) were studied during the browning of agaricus bisporus mushroom cover. The correlation of these changes and browning was discussed and equations between color indices and browning degree were developed. Based on it, the prediction models for the browning degree of the postharvest agaricus bisporus was established. The results indicated that, color indices of L*, a*, b* could be used to quantify the browning degree and L* value was most highly correlated to the browning degree and equations between L value and browning degree were developed under different temperatures. Based on $\sum R^2$, the zero-order kinetics model is used as the prediction model for the browning degree of the postharvest agaricus bisporus based on color parameters: Through comparing correlation between predicted values and actual values, the prediction model for the browning degree of the postharvest agaricus bisporus was validated.

Keywords: Agaricus bisporus, browning, mathematial model, mushroom cover

INTRODUCTION

Agaricus bisporus takes advantages of white color, crisp texture, delicious taste and high nutritional value, which has a large area of cultivation in our country. However, Agaricus bisporus is watery and the mushroom cover is unprotected, so it is easy to quality deteriorate after harvest and the sales time and radius of agaricus bisporus are limited (Tian *et al*., 2012; Aiping, 2010). Agaricus bisporus is highly susceptible to cover browning and it can intuitively reflect the shelf quality and shelf life of agaricus bisporus (TianJia, 2010). Browning reaction in fruits and vegetables is recognised as a serious problem in the food industry. The browning of mushrooms upon storage is a rather complex process (Mac Canna and Gormley, 1968). So the determination of the browning degree is very important to determine the shelf quality of postharvest agaricus bisporus. Traditionally, people evaluate the degree of browning with naked eyes and chemical test. This, however, may not reflect the real situation of browning because the sensibility of the eyes varies with persons and with light density and thus the results may differ greatly (Wu *et al*., 2006). Loredana *et al*. (2011) developed a multispectral vision system to evaluate enzymatic browning in fresh-cut apple slices. The chemical method is destructive and labor-consuming. Thus, developing a rapid simple and accurate browning determination method is necessary.

Enzymatic browning reactions limit the commercial shelf life of apple juice, so that color preservation during storage is one of the main objectives of fruit processors (López-Nicolás *et al*., 2007). Hunter is a new way to evaluate the color changes of fruits and vegetables. With a colorimeter, colors can be quantified in the values of L*, a*, b*, C* and h. The way can accurately reflect the color changes of fruits and vegetables and has been successfully used in a variety of browning degree testing.

In this study, on the basis of pre-research results, using the color parameters of agaricus bisporus to reflect the browning degree can provide a new way for the browning degree detection.

MATERIALS AND METHODS

Materials: Agaricus bisporus were harvested from cooperation in Xingyue, Tianjin. Agaricus bisporus were stored in a cold room at (4±1) °C. Fresh-keeping packaging films in thickness as 0.04 mm were bought from modified atmosphere packaging lab in Tianjin. The foamed PP tray in size as 15*11*2 cm also was bought from modified atmosphere packaging lab in Tianjin.

Corresponding Author: Hu Yunfeng, Key Laboratory of Food Nutrition and Safety, Ministry of Education, Tianjin University of Science and Technology, Tianjin 300457, China

Table 1: The grading standard of browning of Agaricus bisporus at storage

Grade	Color
1	White
2	Color change slightly
3	Color burn
4	Browning slightly
5	Pale brown
6	Puce

Methods:

Treatment of experiment: Agaricus bisporus uniform in size and color were selected, air-dried, quartered and packaged in low density plastic pallet with 90±5 g in each bag before they were stored in temperature humidity chamber at 2, 10, 16, 22°C. And the color indices were detected at the same time.

Indices measurement:

The grading of browning: Refering to (Fei *et al*., 2005) method and slightly modifying, color evaluation criteria is established as Table 1.

Detection of the agaricus bisporus color values: A automatic CR colorimeter was used for determination of color indices. The color indices L*, a*, b* and h were recorded at 5 spots for each agaricus bisporus cover with at least 4 for each treatment.

The color space was defined by L*, a*, b* (CIELAB), where L* stands for brightness and a* and b* are the color coordinates, positive value of a* stands for red color direction and minus value for green; positive value of b* represents the achromatic area (Wu *et al*., 2006).

Detection of the BD: Samples is mixed with boiling water in mass ratio as 1:20. Soak time was 30 s and the speed of translation stage was 1000 r/min for the whole centrifugalization at 5 min. Then, determine absorbance of the supernatant at the wavelength of 410 nm and calculate the browning degree as followed:

$$BD = A\,410 * 20$$

Graphing and analysis: SPSS v19.0 for Windows was used for data treatment and difference analysis. Matlab 2012 was used for correlation analysis and model fitting.

RESULTS AND ANALYSIS

Changes in the grading of browning: As shown in Table 2, with the increase in degrees of cover browning, the browning grade of agaricus bisporus changes obviously in 16 and 22°C. Based on Table 1, agaricus bisporus over grade 5 in sensorial evaluation is losing sale value.

Changes in color indices during mushroom cover browning: As shown in Fig. 1, with the increase in degrees of cover browning, the L* value all decreased and the downtrend was tardy at low temperature. The

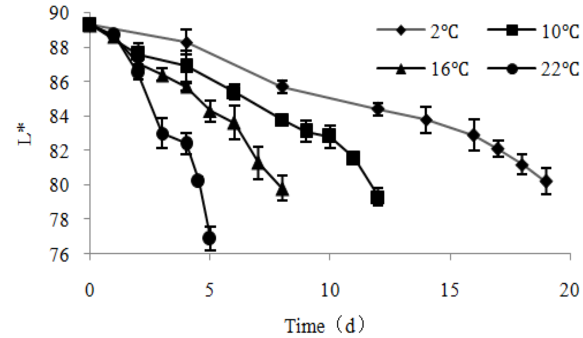

Fig. 1: Changes in L* indices of agaricus bisporus during storage

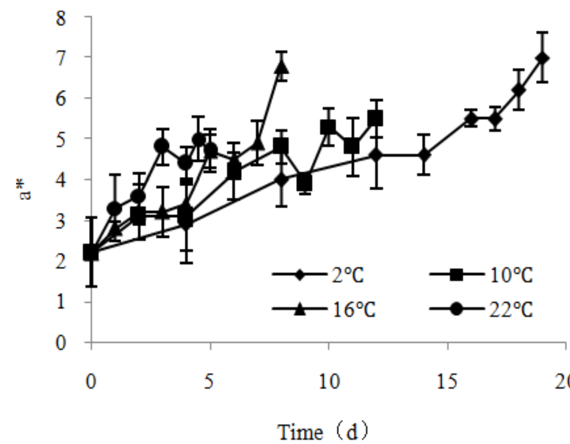

Fig. 2: Changes in a* indices of agaricus bisporus during storage

Table 2: The grading of browning of agaricus bisporus at storage

Temperature	The second day	The fifth day	The eight day	The tenth day
2°C	1	2	3	4
10°C	1	3	4	5
16°C	1	3	5	6
22°C	1	5	6	6

L* value of agaricus bisporus was respectively 85.7 and 80.4 at 2, 16°C after 8 d. And The L* value of agaricus bisporus was as low as 80.4 and the sensorial evaluation of agaricus bisporus was losing sale value.

As shown in Fig. 2 and 3, a* and b* values all increased during different temperatures, but b* values changed obviously. As shown in Fig. 4, h decreased from 80 to 73 (browning seriously) and the changing trend was irregular.

As shown in Fig. 5, C* values rised rapidly at high temperature. The C* values of agaricus bisporus were respectively 27.5 and 32.0 at 16, 22°C after 5 d. And The C* value of agaricus bisporus was as high as 32.0 and the sensorial evaluation of agaricus bisporus is losing sale value.

Changes in BD during mushroom cover browning: Browning degree is the most important indicator and it can result in other sensory qualities. As indicated in

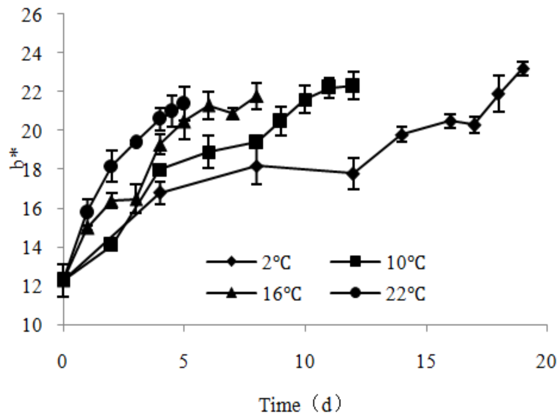

Fig. 3: Changes in b* indices of agaricus bisporus during storage

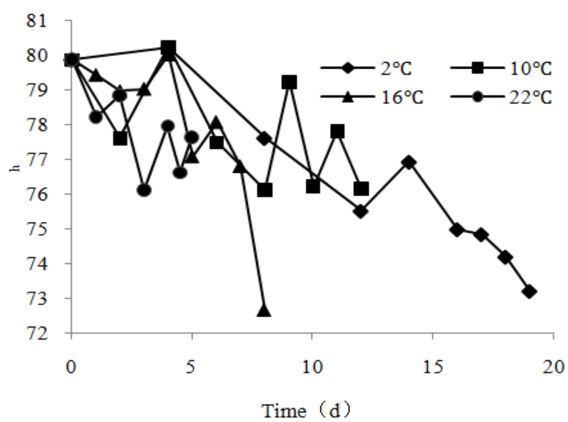

Fig. 4: Changes in h indices of agaricus bisporus during storage

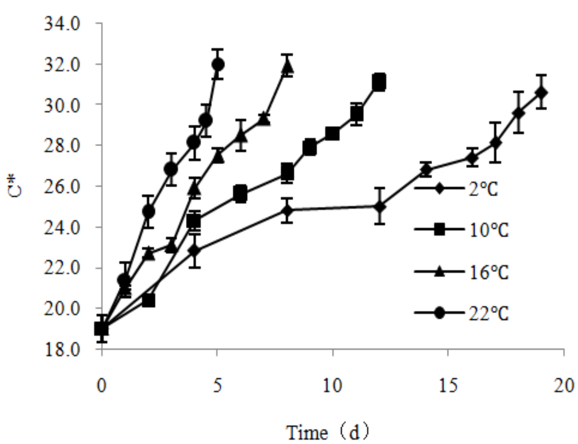

Fig. 5: Changes in C* indices of agaricus bisporus during storage

Fig. 6, BD values all increased and the browning was more serious at the higher the temperature. BD had been on a low level at 2°C. BD changed slightly at beginning from 10 days in storage and rised rapidly after 14 days. BD reached the maximum at 19th day.

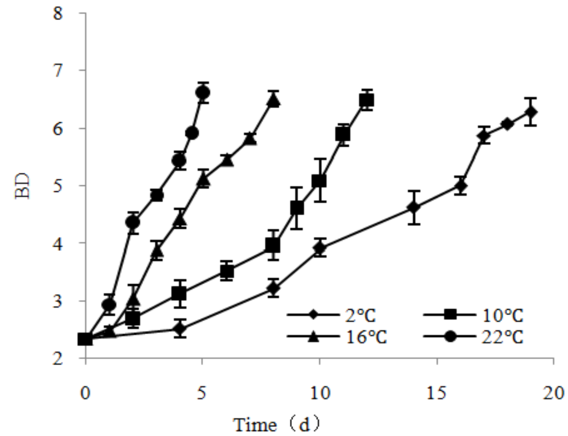

Fig. 6: Changes in browning degree of agaricus bisporus during storage

Table 3: The correlation of BD and color parameters

Temperature °C	BD and L*	BD and b*	BD and C*
22	0.9435	0.9295	0.9933
16	0.9523	0.9109	0.9752
10	0.9612	0.8218	0.8925
2	0.9400	0.8093	0.8869

The correlation between different color indices and the browning degree: As indicated in results above, a* and b* value alues all increased during different temperatures, but b* values changed significantly, so the correction a* between with BD is less than b*.

Figure 4, the temperature could influence the h value to few extent and the changing trend is irregular. Thus, h value cannot reflect the browning degree during different temperature.

Table 3 shows that the browning degree of all the temperatures was highly correlated with L*, a*, b* and C* ($p<0.05$). L* among all color indices was most significantly correlated to browning degree in all temperatures (0.9435, 0.9523, 0.9612, 0.9400). L* value can reflect the browning degree as (Liu, 2010) indicated.

Equations describing the relationship between browning degree and L*, a*, b* and C* values are listed in Table 4.

Establishment of the prediction models for the browning degree: Table 5 shows that rate constant k for the zero prediction model is higher than the first prediction model. The zero prediction model is more accurate than the first prediction model. So the zero prediction model based on L* value is used as the prediction models for the browning degree of the postharvest agaricus bisporus.

According to regression equation and rate constant k calculated by Arrhenius equation, the prediction model for the browning degree of the postharvest agaricus bisporus based on L* value was established as followed:

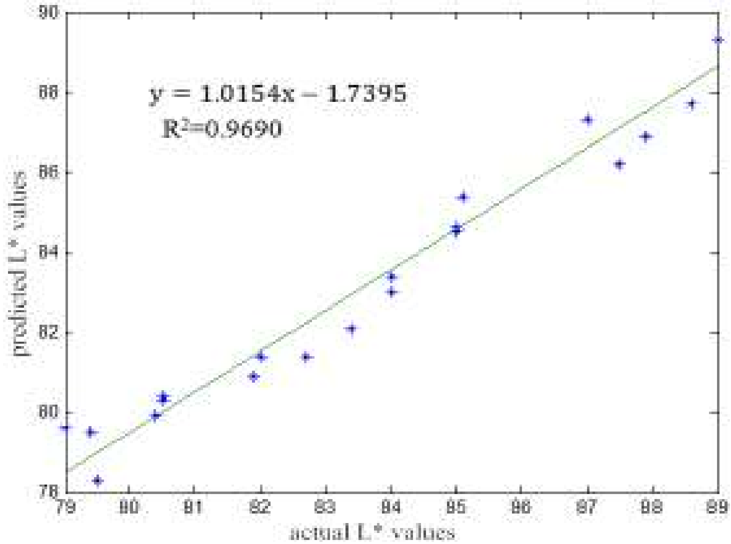

Fig. 7: Correlation between predicted values and actual values of prediction model

Table 4: The linear equation of BD and color parameters

Temperature °C	BD and L*	BD and b*	BD and ΔE
22	y =-2.8511x+97.0699	y = 2.0528x+8.8727	y = 2.9061x+12.4182
16	y =-2.0648x+94.0812	y = 2.0947x+9.1335	y = 2.7858x+13.3462
10	y =-2.1696x+93.4970	y = 2.2343x+9.4544	y = 2.6795x+14.6675
2	y =-1.9406x+92.8736	y = 1.8924x+10.6385	y = 2.2123x+16.2623

Table 5: Rate constant k and determination coefficient R^2 of determination for the zero and first prediction model based on L* indices

		Zero		First	
Indices	Temperature (°C)	Rate constant k	Determination coefficient R^2	Rate constant k	Determination coefficient R^2
L*	2	0.4590	0.9768	0.0054	0.9733
	10	0.7470	0.9648	0.0088	0.9587
	16	1.1500	0.9753	0.0136	0.9708
	22	2.3631	0.9391	0.0282	0.9305
$\sum R^2$			3.856		3.833

$$L^*=L_0-7.22\times10^9\exp\left(\frac{-6474.3}{T}\right)t$$

Verification of the prediction model: Compare predicted L* values calculated by L* value prediction model and actual values (Fig. 7). The result shows, the determination coefficient R^2 based on predicted values and actual values is 0.9690 and average relative error is less than 10%. Thus, the model can predict the browning degree.

DISCUSSION

Agaricus bisporus cover displays a bright white color at maturity, the cover gradually becomes brown and dark during storage at room temperature, resulting in reduction in nutritive value and deterioration in quality (Liu and Wang, 2011). The existence of damaged areas on mushroom surface tissue caused by browning is the most common and challenging quality defect encountered in the mushroom industry.

So far most studies on the browning degree are largely based on visual observation. Vanoli *et al*. (2014) aimed at studying the feasibility of Time-Resolved Reflectance Spectroscopy (TRS) to nondestructively detect Internal Browning (IB) in 'Braeburn' apples through the development of classification models based on absorption (μa) and scattering ($\mu s'$) properties of the pulp (Vanoli *et al*., 2014). Others use chemical methods (Wu *et al*., 1995; Yueming, 2000), which involves the extraction of the brown substances from the pericarp and the measurement of the absorption of the long wavelength light. But this method is complex and has great error.

Color indices have been used in many fruits and vegetables to reflect the processes of ripening and senescence with changes in color. Ren *et al*. (2005) reported that the b* value is corrected to the first dynamical model during packaged and exposed storage for green cauliflower. As it was significantly correlated with the grading of etiolation, b* value could be used as the quality model. Zheng and Xu (2011) reported that, the -a*/b* can reflect the color changes of samples. Rivera-López *et al*. (1999) observed changes in the values of L*, a* and b* during the development of litchi fruits. However, there have been few reports so far on the relationship between the color indices and the browning degree of mushroom cover.

This study shows that all the color indices except h were significantly correlated with browning degrees in agaricus bisporus during different temperature. The L* value was most significantly ($p<0.05$) correlated with browning degrees among all color indices. A linear equation between L* value and the browning degree was thus worked out and the prediction model for the browning degree of the postharvest agaricus bisporus based on L* value was established. The prediction model for the browning degree based on L* value was very close to the actual browning degree.

In actual production, using colorimeter to detect the color indices can conveniently reflect the color changes during storage for agaricus bisporus. The prediction model for the browning degree of the postharvest agaricus bisporus based on L* value can predict the browning degree and the model may have a potential use for the commercial production on freshing-line.

CONCLUSION

Color indices of L*, a*, b* and C all can be used to indicate the color changes of agaricus bisporus and L* value is most significantly correlated to the browning degree during storage for agaricus bisporus at different temperatures. The prediction model for the browning degree of the postharvest agaricus bisporus based on L* value is available for the prediction of agaricus bisporus browning.

ACKNOWLEDGMENT

First of all, I would like to extend my sincere gratitude to my supervisor, HuYunfeng, for her instructive advice and useful suggestions on my thesis. I am deeply grateful of her help in the completion of this thesis.

High tribute shall be paid to Ms. Li, whose profound knowledge of English triggers my love for this beautiful language and whose earnest attitude tells me how to learn English.

I am also deeply indebted to all the other tutors and teachers in Translation Studies for their direct and indirect help to me.

Special thanks should go to my friends who have put considerable time and effort into their comments on the draft.

Finally, I am indebted to my parents for their continuous support and encouragement.

REFERENCES

Aiping, Q., 2010. Effects of different storage temperature on the quality of agaricus bisporus. Chinese Horticult. Abstracts, 1: 42-43.

Fei, T., Z. Min, Y. Hanqing *et al*., 2005. Effect of different temperature on vacuum cooled *Agaricus bisporus*. J. Food Sci. Biotechnol., 24(3): 39-43.

Liu, Y., 2010. Study on physio-biochemical changes associated with browning and preservation technology on agaricus bisporus during storage. M.A. Thesis, Huazhong Agricultural University, Wuhan.

Liu, Z.L. and X.Y. Wang, 2011. Advances in post-harvest physiology and fresh-keeping techniques of mushroom (*agaricus bisporus*). Food Res. Dev., 32(11): 183-186.

López-Nicolás, J.M., E. Núñez-Delicadoa, Á. Sánchez-Ferrerb and F. García-Carmona, 2007. Kinetic model of apple juice enzymatic browning in the presence of cyclodextrins: The use of maltosyl-β-cyclodextrin as secondary antioxidant. Food Chem., 101(3): 1164-1171.

Loredana, L., G. Pamela, D. Belén, L. Lourdes and R.G. Luis, 2011. A multispectral vision system to evaluate enzymatic browning in fresh-cut apple slices. Postharvest Biol. Tec., 3: 225-234.

Mac Canna, C. and T.R. Gormley, 1968. Quality assessment of mushrooms: Relationship between moisture loss, colour and toughness of harvested cultivated mushrooms. Mushroom Sci., 7: 485-492.

Ren, K., K. Tu, L.Q. Pan and Y.Y. Chen, 2005. Modeling of the kinetics of color change of broccoli during storage. T. Chinese Soc. Agric. Eng., 8(21): 146-150.

Rivera-López, J., C. Ordorica-Falomir and P. Wesche-Ebeling, 1999. Changes in anthocyanin concentration in lychee (*Litchi chinensis* Sonn.) pericarp during maturation. Food Chem., 65(2): 195-200.

Tian, G.R., A.J. Wang, S.X. Wei and Z.G. Wang, 2012. Research progress about the influence of storage conditions on the physiological and biochemical changes of agaricus bisporus. Acad. Period. Farm Prod. Process., 1: 89-92.

TianJia, J., 2010. Study on the mechanism and regulation of quality deterioration of main edible fungi after harvest. Ph.D. Thesis, Zhejiang University, Zhejiang.

Vanoli, M., A. Rizzolo, M. Grassi, L. Spinelli, B.E. Verlinden and A. Torricelli, 2014. Studies on classification models to discriminate 'Braeburn' apples affected by internal browning using the optical properties measured by time-resolved reflectance spectroscopy. Postharvest Biol. Tec., 91: 112-121.

Wu, Z.X., M.X. Su and W.X. Chen, 1995. A Study of Some Physiological and Biochemical Changes During Browning of Litchi Fruit. China Agricultural Science and Technology Press, Beijing:pp: 221-227.

Wu, Z.X., Z.L. Ji, D.M. Han, W.X. Chen, S.J. Zhu and M.X. Su, 2006. A study of mathematical models for determining the browning degree of litchi pericarp. J. Fruit Sci., 23(5): 695-698.

Yueming, J., 2000. Role of anthocyanins, polyphenol oxidase and phenols in lychee pericarp browning. J. Sci. Food Agr., 80: 305-310.

Zheng, Y.H. and F. Xu, 2011. A prediction model for chlorophyll content in post-harvest broccoli based on color parameter changes. Food Sci., 32(13): 54-57.